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PUBLICATIONS

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WASHBURN OBSERVATORY

OF THE

UNIVERSITY OF WISCONSIN.

VOL. IX.

PART 1.

INVESTIGATION OF THE ABERRATION AND ATMOSPHERIC REFRACTION.

BY GEORGE C. COMSTOCK.

PART 2.

DETERMINATIONS OF RIGHT ASCENSION.

BY ALBERT S. FLINT.

MADISON, WIS.:
DEMOCRAT PRINTING COMPANY, STATE PRINTER.
1896.

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BY GEORGE C. COMSTOCK,
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The Washburn Observatory,

FOUNDED BY

Cadwallader C. Washburn.

Born 1818; Died 1882.

INTRODUCTION.

The immediate incentive to the following investigations was the suggestion by M. Loewy of the extended use of the equatorial telescope and its adaptation to new lines of research through the introduction of reflecting surfaces in front of the objective. A comparison of the following pages with M. Loewy's printed papers will show that in many respects I have deviated widely from his methods in the application of the principle suggested by him, and it seems proper to state that this deviation arises mainly from the circumstance that I have independently worked out what seemed to me advantageous methods in ignorance of his development of the subject, his papers not becoming accessible to me until after I had become committed to methods and an instrument of my own design.

For pecuniary aid in the construction of this instrument I am indebted to the trustees of the Watson fund of the National Academy of Sciences, who placed the sum of eight hundred dollars at my disposal for this purpose. I take this opportunity of expressing to the gentlemen composing the board of trustees of that fund, Messrs. Simon Newcomb, B. A. Gould and Asaph Hall, my thanks for the confidence thus extended to my attempts at applying what was then a new and untried method of research.

The fundamental idea of the prism apparatus designed by M. Loewy and described in a series of papers published in the *Comptes Rendus de l' Académie des Sciences*, *Vol. CIII.*, *et seq.*, is that if two reflecting surfaces be placed in front of the objective of a telescope in such a manner as to reflect into the objective images of different portions of the heavens, the angular distance separating any pair of stars whose images are thus formed in the telescope, may be found by adding to twice the angle between the reflecting surfaces the angular distance between the images of the stars. This latter quantity may be determined with great precision by means of a filar micrometer, but the angle between the reflecting surfaces does not admit of very precise determination, and the observing programme proposed by M. Loewy is a purely differential one, from which the angle between the reflecting surfaces is eliminated.

It is evident that if instead of two mirrors, three or any greater number be employed and be so placed as to make approximately equal angles one with another, the mean value of the angles formed by the several pairs of mirrors will be determined by purely geometrical considerations, *e. g.* in the case of three mirrors this angle will be 60°, and if each pair of mirrors be employed in the determination of the micrometer distance between the images of the stars as seen in the field of the telescope, the absolute angular distance between the stars will be 120° plus the mean of the three measured distances. The distance between any pair of stars approximately 120° apart may therefore be measured by employing three mirrors; and it may be noted that no other distance admits of such a determination, since if four mirrors be employed the corresponding distance becomes 180°, and it is practically impossible that both stars should be simultaneously visible, and *à fortiori* for any greater number of mirrors.

All of the observations which it is the purpose of the present memoir to set forth and discuss are measurements of the angular distance between stars approximately 120° apart, and such a distance will hereafter be denoted by the symbol $\varDelta$.

In my first design of an instrument adapted to observations of this kind, the reflecting surfaces were the silvered faces of an equiangular glass prism supported in front of the objective of an equatorially mounted telescope, with the axis of the prism perpendicular to the line of sight. The theory of the apparatus, hereafter developed, indicates the following requirements which must be satisfied by the mechanical construction.

(*a.*) The prism must admit of rotation through 360° about a line approximately coincident with its own axis

(*b.*) The axis of the prism must admit of rotation through 360° about a line approximately coincident with the line of sight of the telescope.

(*c.*) The prism must be so supported that neither of these rotations shall have any systematic effect in distorting the figure of the reflecting surfaces.

(*d.*) It is obviously a matter of practical convenience that the rotations (*a*) and (*b*) should be effected from the eye end of the telescope, and I adopted this as a further condition to be satisfied.

The apparatus was to be attached to the six-inch Clark equatorial telescope in the "Student's Observatory" of the University of Wisconsin. This telescope was formerly the property of Mr. S. W. Burnham, and its optical excellence may be inferred from the large amount of double-star work, both measurement and discovery, done with it by Mr. Burnham. The objective has a clear aperture of 152 *mm.* and a focal length of 2,384 *mm.* It is mounted in a wooden tube carried by a light equatorial mounting of the ordinary Clark type, and is provided with an excellent driving clock. The filar micrometer which constitutes an essential part of the apparatus is described in a subsequent section devoted to its investigation.

The equiangular glass prism which was to furnish the reflecting surfaces was prepared for me by Mr. J. A. Brashear, who informs me that he experienced great diffi-

culty in figuring the surfaces by reason of changing temperature distorting the edges of the prism more rapidly than its central portions. "Our standard test plate is one half inch thick, the prism being so heavy the effect of merely opening a door could be seen in less than fifteen seconds, and the only way we were *sure* of the surface was to leave the test plate on prism for a night, light the sodium flame and test im mediately."

Since distortions of this character finally compelled me to abandon the use of the prism and to substitute for it another device, a summary description of this part of the apparatus will suffice.

The prism was a single block of glass, each of whose silvered faces was 128 *mm.* square, save that the corners were rounded off to prevent chipping. The prism was supported by brass cheeks let into and cemented to its triangular bases, and to each of these cheeks there was attached by suitable adjusting screws a circular brass plate with an aperture 5 *mm.* in diameter drilled in its center. By means of the adjusting screws these apertures were to be brought into the axis of the prism, and were to form the bearings for a pair of pivots supported near and in front of the edges of the objective of the telescope. These pivots constituted an axis about which the prism was to be rotated by an endless cord extending to the eye end of the telescope.

The distance of the pivots in front of the objective was very approximately 150 *mm.*, and they were supported by a brass casting whose form and position with respect to the telescope are shown in the plate giving a general view of the telescope and dome. By means of four capstan-headed adjusting screws placed 90° apart the casting was attached to each of two stout metallic rings firmly bolted to the upper end of the telescope tube, and by means of these screws the prism could be brought into a position symmetrical with respect to the line of sight of the telescope. No part of the supports of the prism came in contact with the objective or its cell.

To secure a rotation of the prism about the line of sight (Condition *b*) the original connection between the telescope tube and the declination axis was replaced by a simple form of heliometer cradle with handles for rapid and slow rotation of the tube. A divided circle reading to minutes of arc was attached to the eye end of the tube in order to measure the amount of rotation of the telescope in its cradle. Since this rotation corresponds to and is measured by an angle which in the theory of the apparatus is represented by the symbol P, this circle will be called the P circle. Although the cradle was provided with ball bearings for the support of the telescope, the motion of the tube proved to be rather stiff, and was the source of some inconvenience in the conduct of the observations.

It will be recognized from the preceding description that the two faces of the prism which are employed as mirrors in any given observation, stand over opposite halves of the objective, and it is well known that this unsymmetrical distribution of the incident light will produce errors in the measured distance between the star images unless the micrometer threads are placed exactly in the focal plane of the objective. In order to control the focal adjustment of the telescope with all possible precision

I attached to the draw tube a nut carrying a micrometer screw, which I designate the longitudinal micrometer. As the focussing screw is turned the nut is moved out or in, parallel with the line of sight of the telescope, and small changes in the distance of the filar micrometer threads from the objective may be very precisely determined by turning the longitudinal screw until its point abuts against a fixed plate attached to the end of the telescope tube, and noting the reading of its head.

Between the prism and the objective of the telescope I introduced an opaque cap pierced with two circular apertures approximately 60 *mm.* in diameter and symmetrically placed on opposite sides of the center of the cap. In the ordinary use of the telescope the cap was so placed that the line of centers of the apertures was perpendicular to the axis of the prism, thus bringing the apertures under opposite mirrors and securing good definition and round images of the stars. To test the focal adjustment of the instrument the cap was turned until the line of centers was parallel to the axis of the prism and the light from a bright star was reflected from one face of the prism into both apertures. If the telescope were perfectly focussed all of the rays of light passing through the objective should be collected at one point and form a single image of the star, while if the focal adjustment was very greatly in error the rays of light passing through the two apertures would form two, more or less confused images of the star.

I have shown, *Astr. Jour. No. 171*, that the angular distance between these images is given by the equation

$$d = 206265\,\frac{b_1-b_2}{f^2}\cdot q \tag{1}$$

where b_1—b_2 is the linear distance between the centers of the apertures, f the focal length of the objective and q the error of focusing. It was my practice to give to q first a positive and then a negative value sufficiently great to separate the images of the star observed, to note the corresponding readings, a and b, of the longitudinal micrometer and to measure the distances, A and B, between the images with the filar micrometer. If c be the reading of the longitudinal micrometer corresponding to an accurate adjustment of the focus we shall have, *loc. cit.*

$$c = \frac{a+b}{2} - \frac{a-b}{2}\cdot\frac{A-B}{A+B} \tag{2}$$

and for any observation made with a focal adjustment corresponding to the reading x of the longitudinal micrometer the correction for mal-adjustment of focus will be given by

$$\Delta d = 206265\,\frac{b_1-b_2}{f^2}(x-c) = +0''.616\,(x-c). \tag{3}$$

It was my purpose to determine the quantity c with sufficient frequency to permit its value to be interpolated for each observation of the distance between a pair of stars, but experience has shown this to be a matter of great difficulty, if not altogether impracticable, since the figure of the reflecting surfaces, upon which the focal length of the combination mirror + objective depends, varies in a complicated manner not only with the temperature but with the rate of change of the temperature.

Variations in the focal length of the apparatus and in the focal adjustment may conceivably arise from other causes than the above, but that deformations of the reflecting surfaces are present in sufficient degree to account for the observed changes is independently indicated by a series of observations of the position angles of the images produced by throwing the telescope out of focus as above described. I extract the following observation and note from my record of Oct. 7, 1890:

	Focus on ι Ceti.	*Mirror 1.*	
Longitudinal Micrometer,	48.88	15.99	*revolutions.*
Position Circle,	81°.3	96°.6	

"*It appears from the above that the position angle of the images changes 15° when the setting is changed from one side of focus to the other.*" If the mirror were a plane surface the line joining the images produced by throwing the telescope out of focus must be parallel to the line joining the centers of the apertures in the cap and the observed change in the direction of the former line indicates either a curved or, more probably, a warped surface for the mirror.

The apparatus was placed in the "Students' Observatory" of the University of Wisconsin, a small wooden building adjoining the Washburn Observatory, and represented in the foreground of the frontispiece. A description of the building is given in Vol. I., Publications W. O., and so much of that description as is pertinent to the work with the prism apparatus I reproduce here.

"The building, which is entirely of wood, faces the south and is of one story throughout. A shallow cellar of about 4 feet deep is under the whole floor."

"The entrance from the south is into a hall 7.4 feet (north and south) by 6.3 feet (east and west). This hall is lighted by two windows, one north, the other west. From this hall a door to the east enters the dome. The radius of the spherical dome is 6.7 feet. * * * * The dome is supported upon an octagon structure, the *inner* sides of the joists forming one side of the octagon being 4.5 feet. The northwest side of the octagon is omitted and the angle of the walls is there a right angle, to join the walls of the hall. The floor of the dome was originally 8 feet 5 inches below the turning part, but to fit it to receive a six-inch equatorial a second floor has been put in some 2.5 feet higher." * * * *

"*The Equatorial Pier:* This is built of selected red brick laid in cement and rubbed down to shape. It is 8 feet 6 inches above the (present) floor."

It is evident that the ordinary form of dome will not permit the simultaneous observation of stars 120° apart. In order to secure the simultaneous visibility of the stars I removed one half of the dome, leaving only the base ring, and that part of the hemispherical shell which lay upon one side of a vertical plane passing through the axis of the dome. Upon the base ring of the original dome another concentric sliding ring was placed, and this ring carried half of a hemispherical shell of slightly greater radius than the original dome. By rotating the upper upon the lower ring the relative position of the two half-hemispheres may be changed, *e. g.*, they may be made to stand one over the other, leaving a clear opening from below the horizon to

within about 10° of the zenith, and extending over 160° in azimuth. When the larger half-hemisphere is placed opposite to the smaller one, they together constitute a closed and water-proof dome. A cut of the dome showing it opened for observation faces p. 6. This arrangement has proved exceedingly convenient, and possesses the great merit that during observation the instrument is virtually placed in the open air, the dome being reduced to little more than a screen placed at one side of the telescope.

In order to familiarize myself with the apparatus thus described, in the autumn of 1889 I made a short series of observations of six pairs of stars. At this time the theory of the instrument was imperfectly understood, and precautions in the adjustment and determination of instrumental constants which were subsequently adopted were here neglected from ignorance of their necessity. Chief among these is the correction which in the theory of the apparatus I have represented by the symbol K.

These observations showed what I had suspected *à priori*, that the focal length of the apparatus varied in a marked degree even during a single evening, and that it was a matter of extreme difficulty to determine the instantaneous value of the error of focusing, with sufficient precision to permit of its use as a correction term for the observations.

The individual observations of this series are presented in the following table, in which the columns d, R, $Ab.$ and $F.$ represent respectively the measured distance between the star images, the computed effects of refraction and aberration, and the correction for focus.

I. α Piscium. α Leonis.

Date.	*d*	*R*	*Ab.*	*F*	*Obs'd Δ*
	′ ″	′ ″	″	″	° ′ ″
1889 Oct. 1	+3 29.41	+3 19.37	+34.42	−0.43	120 7 22.8
2	34.85	11.98	34.32	+ .13	21.3
3	27.16	20.08	34.19	− .15	21.3
5	22.91	24.07	33.90	−1.86	19.0

II. γ Ceti. *l* Leonis.

	′ ″	′ ″	″	″	° ′ ″
1889 Oct. 3	+5 7.42	+3 20.98	+34.95	−0.15	120 9 3.2
5	2.78	24.67	34.89	−1.86	0.5
7	3.07	23.89	34.77	+0.40	2.1

XIII. β Libræ. γ Piscium.

Date.	d	R	Ab.	F	Obs'd Δ
	′ ″	′ ″	″	″	° ′ ″
1889 Sept. 17	+5 20.40	+8 18.07	−31.19	0.00	120 8 2.8
18	20.89	12.90	31 42	+ .47	2.8
20	26.54	8.44	31.85	+ .87	4.0
27	26.91	9.72	33.07	+ .80	4.4
28	29.00	7.78	33.20	− .22	3.4
30	28.92	6.85	33.44	+1.42	3.8
Oct. 1	24.93	11.68	33.55	+1.30	4.4
3	26.06	10.96	33.74	+ .98	4.3
7	23.37	16.33	33.98	+ .25	6.0

XIV. 3 Serpentis. φ Aquarii.

	′ ″	′ ″	″	″	° ′ ″
1889 Sept. 15	+1 52.32	+8 11.15	−29.95	+3.03	120 4 36.6
17	52.92	13.78	30.42	.00	36.3
18	53.21	13 36	30.63	+ .47	36.4
20	56.10	9.82	31.05	+ .80	35.7
21	52.39	13.60	31.24	− .25	34.5
27	57.69	10.67	32.18	+ .80	37.0
30	60.62	7.06	32.53	+1.42	36.6
Oct. 1	54.79	12.35	32.62	+1.30	35.8
3	57.83	12.10	32.78	+ .98	38 1
7	54 02	17.31	33.01	+ .30	38.6

XV. δ Ophiuchi. ι Ceti.

	′ ″	′ ″	″	″	° ′ ″
1889 Oct. 1	+5 11.98	+8 11.91	−32.49	+1.33	120 7 52.7
3	13.55	11.85	32.94	+0.81	52.8
7	12.19	17.12	33.71	+0.57	56.2

XVI. *ε* Serpentis. 108 Aquarii.

Date.	*d*	*R*	*Ab.*	*F*	*Obs'd Δ*
	′ ″	′ ″	″	″	° ′ ″
1889 Sept. 17	−7 20.83	+3 11.66	−31.13	0.00	119 55 19.7
18	18.02	11.03	31.41	+ .47	22.1
20	16.05	8.50	31.92	− .07	20.5
27	15.01	8.57	33.44	+ .80	20.9
30	12.16	3.86	33.94	+1.42	19.2
Oct. 1	18.07	10.73	34.10	+1.30	19.9
3	15.81	10.44	34.38	+ .98	21.2

From the first powers of the 36 residuals furnished by these observations, I find as the probable error of a single observation, $r_1 = \pm\ 0.''82$, from which it appears that the observations are not sufficiently precise for an investigation of the aberration.

A more complete understanding of the theory of the apparatus than I possessed at the time these observations were made suggests precautions which would doubtless lead to some amelioration of the results furnished by the apparatus, but the fundamental difficulty, the deformation of the prism arising from changes of temperature and producing errors of focus, appears to me insuperable with this type of apparatus. I have therefore directed my attention to the construction of an apparatus in which this source of error should be avoided.

Equation 1 indicates that the error represented by F in the table above may be obviated either by perfect focusing, $q = 0$, or by constructing the apparatus to satisfy the condition

$$b_1 - b_2 = 0$$

for all adjustments of the focus. This quantity has been above defined as the distance between the apertures in the cap, and for the purpose of the preceding discussion that definition was sufficient. It may be seen, however, from the article in which the equation is derived, that in general, $b_1 - b_2$ is the projection of this distance upon the line along which the micrometer distance is to be measured, and that if the cap be so placed that the line determined by the centers of the apertures is parallel to the micrometer threads, then $b_1 - b_2 = 0$, and even gross errors of focusing will have no effect upon the measured distances. It must not be inferred that an error of focusing will have no effect upon the position of the stars in the field of view, but only that it has no effect upon the measured distance when that distance is perpendicular to the line of the apertures.

To secure this advantage I have discarded the prism and have substituted for it three plane mirrors of rectangular cross section and equal size, $160 \times 50 \times 25$ *mm.*, which were constructed for me by Mr. Brashear. Each of these mirrors is silvered on all of its surfaces, although only one surface is polished, in order to secure as far as possible equality of radiation and absorption of heat and uniformity of temperature throughout the mirror. Mr. Brashear informs me that these mirrors were cut with a diamond saw from a circular block of glass ten inches (254 *mm.*) in diameter. This block was ground, silvered and polished as a single mirror, and after the three mirrors had been cut from it they were tested and found to be indistinguishable one from another in respect of curvature.

These mirrors were to replace the three faces of the prism, and to secure them in their proper positions with respect to each other and to the telescope, I had constructed by Mr. Saegmuller a reel having two circular end plates of brass, 208 *mm.* in diameter and 10 *mm.* thick. These plates were firmly joined together by six brass beams of cross section like the letter Y, and three round tie rods of brass, each placed between a pair of Y beams. These tie rods and beams were all placed near the circumference of the end plates, leaving the central parts of the reel free for the reception of the mirrors, which were supported by adjusting screws with opposing springs in such a manner that the surface of each mirror could be made parallel to the axis of the reel, could be made to pass through the axis of the reel, and could be rotated about this axis so as to make the angles between the reflecting surfaces very approximately 60°. The distance between the inner faces of the end plates of the reel exceeds the sum of the widths of the three mirrors by about half a millimeter, furnishing abundant room for the adjustment of the mirrors without interfering one with another. For the details of the construction see Figs. I, II, III and IV. Fig. I is a projection of the reel upon a plane perpendicular to its axis. Fig. II is a projection upon a plane passing through the axis, and the shaded portions represent the intersections of this plane with the mirrors and parts of the reel. Figs. III and IV show the arrangement of adjusting screws and springs by which the mirrors were held in place.

The springs whose pressures hold the mirrors in place were applied to the back surfaces of the mirrors, while the reflecting surfaces bore against the adjusting screws. In the construction of the reel great care was taken that the axis of each spiral spring should be exactly opposite the bearing point of its opposing screw, in order to avoid the distortion of the mirrors which would result from an unsymmetrical application of stresses to them. The reel was supported upon the same pivots which had been used with the prism, and the endless cord with which the prism was rotated about its axis was carried in a groove about one of the end plates of the reel.

For the purpose of improving the definition an opaque cap or screen with three circular apertures was introduced between the reel and the objective. The diameters of these apertures were very approximately equal to the widths of the mirrors, and

their centers lay upon a diameter of the cap which was adjusted parallel to the axis of the reel, so that in effect the objective of the telescope was replaced by three objectives, each of 50 *mm.* diameter. Each of these parts of the objective was completely filled by a beam of light reflected from the central portion of one of the mirrors and so situated that the axis of each beam intersected the axis of the reel, thus satisfying the condition $b_1 - b_2 = 0$. If the course of each of these beams be traced through the reel it will be found that the Y beams and tie rods are so placed that at no point do they impinge upon either the incident or reflected beam from any mirror.

The several mirrors are numbered 1, 2, 3; 1 being nearest to and 3 farthest from the end of the reel about which the cord passes, and as in the prism each pair of faces is considered as forming an angle which may be used in the measurement of a distance, Δ, so each pair of mirrors is considered as forming an angle, and these angles are designated by Roman numerals, viz.:

Mirrors 2 and 3 = Angle I.
Mirrors 1 and 2 = Angle II.
Mirrors 3 and 1 = Angle III.

These numerals are lettered upon each end of the reel, so that the observer need have no doubt as to the particular combination of mirrors which is in use at any moment.

To test experimentally the freedom of the distances measured with the apparatus from errors of focusing, on May 3, 1890, I pointed the apparatus upon the pair of stars *γ Geminorum—109 Virginis*, and with the telescope carefully focused, set the micrometer threads to simultaneously bisect the images of the stars. With my eye at the telescope I turned the focusing screw so as to move the micrometer alternately out and in, and watched the appearance of the stars with respect to the micrometer threads, which were placed approximately parallel to a vertical circle. The record in the note-book reads: "Threw the telescope ¼ inch out of focus. Small motion of stars in vertical coördinate, but none in horizontal." The experimental test confirms the indication of theory, that when the axes of the pencils of light reflected from any pair of mirrors fall upon that diameter of the objective which is perpendicular to the arc Δ, errors of focusing have no effect upon the value of Δ measured with the apparatus.

The results of an experimental series of observations made with the reel are given in the following tables, whose arrangement is the same as that of the preceding table of prism observations save that the correction for focus is omitted. The results of both of these preliminary series are worthless for a determination of the distance between the stars observed, since certain minute instrumental corrections to be hereafter considered were not determined simultaneously with the observations, and are necessarily neglected. The results, however, suffice to show the marked advance in precision gained by substituting the reel in place of the prism.

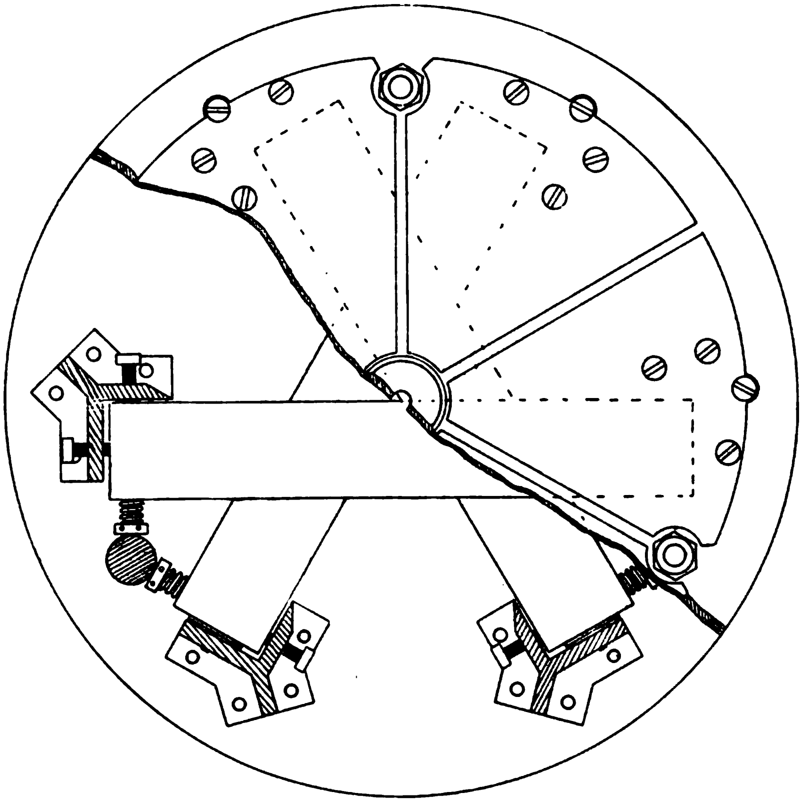


FIG. 1

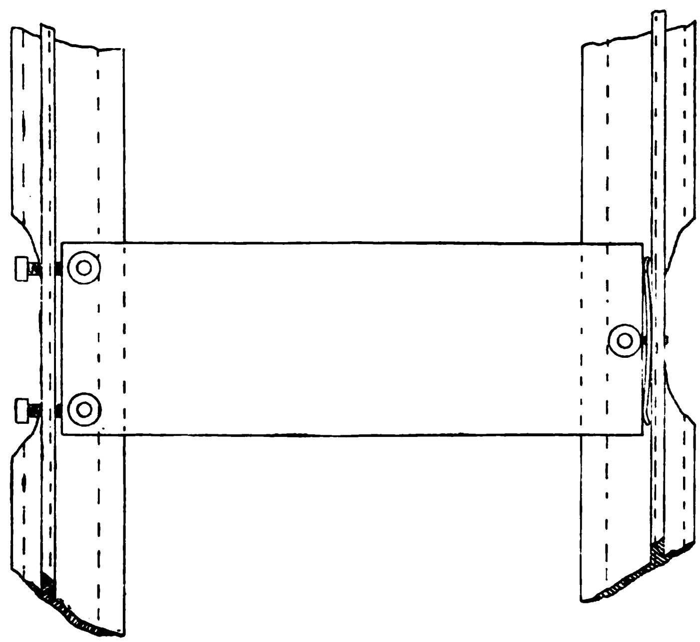


FIG. III

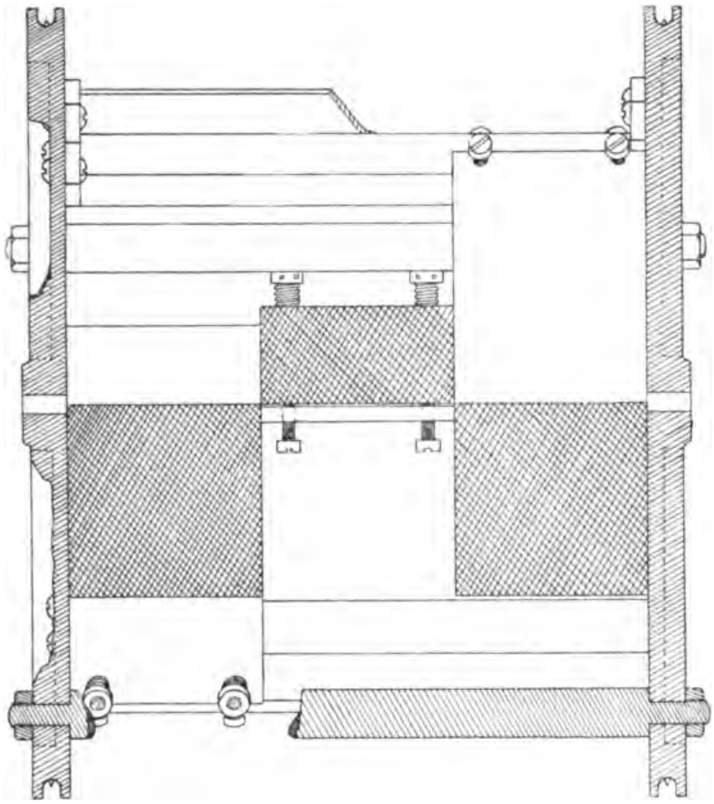


Fig. 11

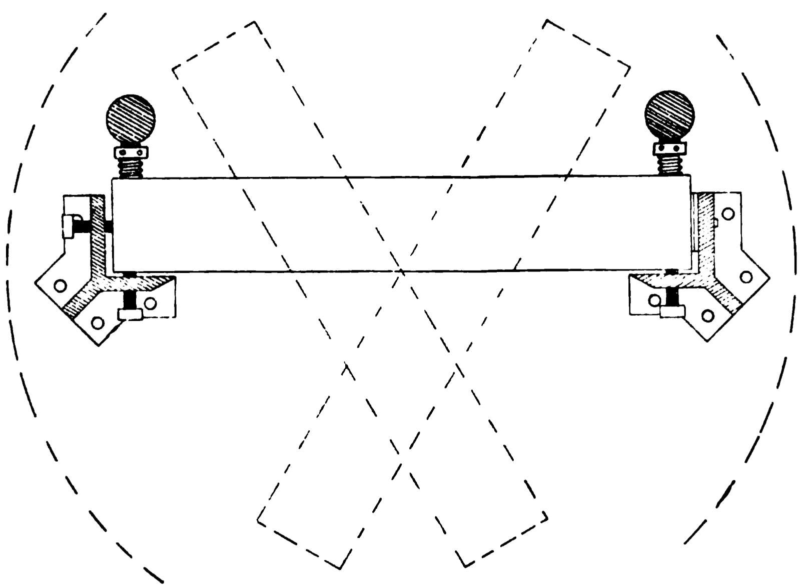


Fig. IV

IX. γ Geminorum. 109 Virginis.

Date.	*d*	*R*	*Ab.*	*Obs'd Δ*	*Remarks.*
	′ ″	′ ″	″	° ′ ″	
1890 May 2	+0 13.65	+3 8.59	−32.14	120 2 50.1	
3	+ 8.14	15.28	32.36	51.1	
8	+ 15.80	8.45	33.35	50.9	
15	− 7.58	32.94	34.31	51.0	Obs'd 40m after epoch.

D (2). ι Hydræ. Ll. 32200.

	′ ″	′ ″	″	° ′ ″	
1890 May 26	−2 29.75	+3 10.31	−24.19	120 0 16.4	Obs'd 30m after epoch.
28	41.91	22.32	25.03	15.4	
30	23.25	5.26	25.83	16.2	
June 6	25.44	9.72	28.41	15.9	

E (2). p^2 Leonis. g Aquilæ.

	′ ″	′ ″	″	° ′ ″	
1890 May 26	−3 57.20	+3 10.45	−13.33	119 58 59.9	
28	50.78	5.18	14.39	60.0	
30	49.58	5.42	15.44	60.4	
June 6	50.44	10.15	18.98	60.7	
7	51.06	12.27	19.45	61.8	
8	49.69	10.22	19.95	60.6	
15	41.24	6.54	23.13	62.2	

F (2). υ Leonis. ι Aquilæ.

	′ ″	′ ″	″	° ′ ″	
1890 May 28	−3 21.30	+3 6.00	−9.88	119 54 34.8	
30	20.24	5.89	10.96	34.7	
June 6	21.21	10.81	14.62	35.0	
7	22.59	12.61	15.14	34.9	
8	19.31	10.39	15.63	35.4	
15	12.60	6.64	19.03	35.0	

From the first powers of the 19 residuals furnished by these observations I find for the probable error of a single observation, $r_1 = \pm\ 0''.38$, which compared with the corresponding number, $\pm\ 0''.82$, for the prism observations indicates a precision more than fourfold greater. The precision obtained in a series of observations extending from September, 1890, to June, 1892, is appreciably greater than the preceding, the probable error resulting from the final discussion of these observations being $r_1 = \pm\ 0''.30$.

THEORY OF THE ERRORS OF THE APPARATUS.

An elaborate theory of the errors of the Loewy prism apparatus has been published in the *Comptes Rendus* by MM. Loewy and Puiseux, but since their apparatus differs in some important respects from that which I have employed, I have preferred to use for the reduction of the observations, formulæ furnished by the following analysis, which was made before the publication of the theory above referred to. The analysis is based upon the following:

Lemma. Given the polar coördinates A and P of the point in which the normal to a reflecting surface meets the celestial sphere, and the coördinates a_1, p_1 of a star, it is required to find the coördinates a', p' of the point in which the ray from the star, after reflection meets the celestial sphere.

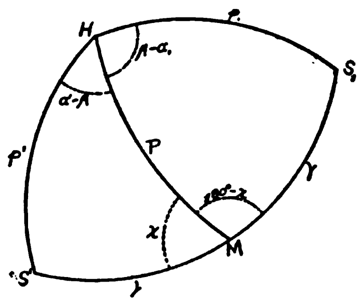


Fig. A.

In Fig. A let H represent the celestial pole, M the point at which the normal to the mirror intersects the celestial sphere, S_1 and S' respectively the star and the required direction of its reflected ray. Since from elementary principles of optics the arcs S_1M, MS' are equal, we have from the spherical triangles involved the following groups of equations, in which A represents the right ascension of M.

$$\begin{aligned} \sin\gamma \sin x &= \sin p_1 \sin(A-a_1) \\ \sin\gamma \cos x &= \cos P \sin p_1 \cos(A-a_1) - \sin P \cos p_1 \\ \cos\gamma &= \sin P \sin p_1 \cos(A-a_1) + \cos P \cos p_1 \end{aligned} \tag{4}$$

$$\begin{aligned} \sin p' \sin(a'-A) &= \sin\gamma \sin x \\ \sin p' \cos(a'-A) &= \sin P \cos\gamma - \cos P \sin\gamma \cos x \\ \cos p' &= \cos P \cos\gamma + \sin P \sin\gamma \cos x \end{aligned} \tag{5}$$

Substituting equations (4) in (5) they become:

$$
\begin{aligned}
\sin p' \sin (a'-A) &= -\sin p_1 \sin (a_1-A) \\
\sin p' \cos (a'-A) &= \cos p_1 \sin 2P - \sin p_1 \cos 2P \cos (a_1-A) \qquad (6) \\
\cos p' &= \cos p_1 \cos 2P + \sin p_1 \sin 2P \cos (a_1-A)
\end{aligned}
$$

which determine a', p' in terms of a_1 p_1 A and P.

In Fig. B let S_1 S_2 represent two stars, of which S_2 has the greater right ascension, and let M be the middle point of the arc Δ which joins them. R is the point of the celestial sphere toward which the rotation axis of the telescope tube is directed, and ξ and η are the spherical coördinates of R referred to M as origin. P

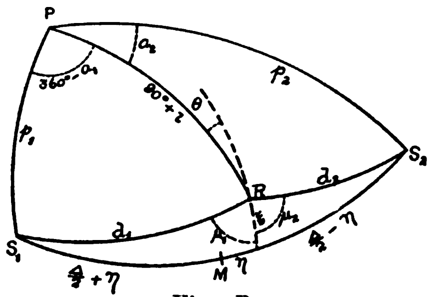


Fig. B.

is the point in which the axis of the reel produced on the north side of the equator meets the celestial sphere, and a_1, p_1, a_2, p_2 are the polar coördinates of S_1 and S_2 in a system in which the axis of the reel is the axis of z and the plane determined by the axis of the reel and the axis of rotation of the telescope tube is the plane of xz. The positive axis of x is directed approximately toward the point R. The arc of a great circle represented by a broken line through R is perpendicular to the arc Δ and the angle θ which it makes with the arc PR is to be reckoned positive when the axis of the reel P is inclined toward S_1. The remaining quantities will be readily understood from the figure, and from it we obtain the following equations:

$$
\begin{aligned}
\sin d_1 \sin \mu_1 &= \sin \left\{ \frac{\Delta}{2} + \eta \right\} & \sin d_2 \sin \mu_2 &= \sin \left\{ \frac{\Delta}{2} - \eta \right\} \\
\sin d_1 \cos \mu_1 &= \cos \left\{ \frac{\Delta}{2} + \eta \right\} \sin \xi & \sin d_2 \cos \mu_2 &= \cos \left\{ \frac{\Delta}{2} - \eta \right\} \sin \xi \qquad (7) \\
\cos d_1 &= \cos \left\{ \frac{\Delta}{2} + \eta \right\} \cos \xi & \cos d_2 &= \cos \left\{ \frac{\Delta}{2} - \eta \right\} \cos \xi
\end{aligned}
$$

$$
\begin{aligned}
\sin p_1 \sin a_1 &= -\sin d_1 \sin (\mu_1 + \theta) \\
\sin p_1 \cos a_1 &= -\sin d_1 \sin i \cos (\mu_1 + \theta) + \cos d_1 \cos i \qquad (8) \\
\cos p_1 &= -\sin d_1 \cos i \cos (\mu_1 + \theta) - \cos d_1 \sin i
\end{aligned}
$$

$$
\begin{aligned}
\sin p_2 \sin a_2 &= +\sin d_2 \sin (\mu_2 - \theta) \\
\sin p_2 \cos a_2 &= -\sin d_2 \sin i \cos (\mu_2 - \theta) + \cos d_2 \cos i \qquad (8') \\
\cos p_2 &= -\sin d_2 \cos i \cos (\mu_2 - \theta) - \cos d_2 \sin i
\end{aligned}
$$

Substituting in equations (8) the values given by (7) and neglecting terms of the order ξ^2, η^2, θ^2, i^2 they become

$$\begin{aligned} \sin p_1 \sin a_1 &= -\sin\left\{\frac{\Delta}{2}+\eta\right\} + \tfrac{1}{2}\theta^2 \sin\frac{\Delta}{2} - \xi\theta\cos\frac{\Delta}{2} \\ \sin p_1 \cos a_1 &= +\cos\left\{\frac{\Delta}{2}+\eta\right\} - \tfrac{1}{2}(\xi+i)^2\cos\frac{\Delta}{2} + i\theta\sin\frac{\Delta}{2} \\ \cos p_1 &= -(\xi+i)\cos\left\{\frac{\Delta}{2}+\eta\right\} + \theta\sin\left\{\frac{\Delta}{2}+\eta\right\} \end{aligned} \tag{9}$$

The corresponding equations for p_2 a_2 are:

$$\begin{aligned} \sin p_2 \sin a_2 &= +\sin\left\{\frac{\Delta}{2}-\eta\right\} - \tfrac{1}{2}\theta^2 \sin\frac{\Delta}{2} - \xi\theta\cos\frac{\Delta}{2} \\ \sin p_2 \cos a_2 &= +\cos\left\{\frac{\Delta}{2}-\eta\right\} - \tfrac{1}{2}(\xi+i)^2\cos\frac{\Delta}{2} - i\theta\sin\frac{\Delta}{2} \\ \cos p_2 &= -(\xi+i)\cos\left\{\frac{\Delta}{2}-\eta\right\} - \theta\sin\left\{\frac{\Delta}{2}-\eta\right\} \end{aligned} \tag{9'}$$

Denoting by A_1 and $90°-h_1$ the coördinates of the normal to the mirror from which the image of the star S_1 is reflected, we obtain from (6) the following expressions for the coördinates of the reflected image:

$$\begin{aligned} \sin p'_1 \sin(a'_1 - A_1) &= -\sin p_1 \sin(a_1 - A_1) \\ \sin p'_1 \cos(a'_1 - A_1) &= +\cos 2h_1 \sin p_1 \cos(a_1 - A_1) + \sin 2h_1 \cos p_1 \\ \cos p'_1 &= +\sin 2h_1 \sin p_1 \cos(a_1 - A_1) - \cos 2h_1 \cos p_1 \end{aligned} \tag{10}$$

with a similar group of equations for the star S_2. Multiply the first of these equations by $\cos A_1$ and the second by $\sin A_1$ and add the products, the sum is easily transformed into:

$$\begin{aligned} \sin p'_1 \sin a'_1 = {} & \sin 2A_1 \sin p_1 \cos a_1 - \cos 2A_1 \sin p_1 \sin a_1 \\ & - 2\sin^2 h_1 \sin A_1 \sin p_1 \cos(a_1 - A_1) + \sin 2h_1 \sin A_1 \cos p_1 \end{aligned}$$

Introducing rectangular coördinates into the first member and neglecting terms of the third order, this equation becomes:

$$\begin{aligned} y'_1 = {} & \sin\left(2A_1 + \frac{\Delta}{2} + \eta\right) - 2h_1^2 \sin A_1 \cos\left(A_1 + \frac{\Delta}{2} + \eta\right) - \tfrac{1}{2}(\xi+i)^2 \sin 2A_1 \cos\frac{\Delta}{2} \\ & - \tfrac{1}{2}\theta^2 \cos 2A_1 \sin\frac{\Delta}{2} - 2h_1(\xi+i)\sin A_1 \cos\frac{\Delta}{2} \\ & + 2h_1\theta \sin A_1 \sin\frac{\Delta}{2} + i\theta \sin 2A_1 \sin\frac{\Delta}{2} + \xi\theta\cos 2A_1 \cos\frac{\Delta}{2} \end{aligned} \tag{11}$$

with a similar expression for y'_2.

In these equations it will always be permissible to put $\sin p_1 = \sin p_2 = 1$, and for the particular instrument with which we are here concerned, since Δ is very approximately equal to 120°, we may write in the second order terms

$$\cos\frac{\Delta}{2} = \cos(a_1 - A_1) = \frac{1}{2}$$

Introducing these special values into equation (11) and writing out the corresponding equation for S_2 we obtain by addition and subtraction:

$$y'_1 + y'_2 = 2 \sin (A_1 + A_2 + \eta) \cos \left\{ A_1 - A_2 + \frac{\Delta}{2} \right\} + L' \qquad (12)$$

$$y'_1 - y'_2 = 2 \cos (A_1 + A_2 + \eta) \sin \left\{ A_1 - A_2 + \frac{\Delta}{2} \right\} + K' \qquad (13)$$

where L' is composed of second order terms whose values are not required in the following investigation, and

$$K' = \sin 60^\circ \left\{ h_1^2 + h_2^2 - \tfrac{1}{2}(\xi + i)^2 + \tfrac{1}{2}\theta^2 + (\xi + i)(h_1 + h_2) - \sqrt{3}\,\theta(h_1 - h_2) \right\} \qquad (14)$$

To interpret equations (12) and (13), it should be noticed that since the axis of x coincides with the rotation axis of the telescope, axis of the cradle, the plane of yz is parallel to the micrometer threads, and if these threads be set at the proper position angle and made to bisect the images of the stars which appear in the focal plane of the objective, the angular distance between the threads gives directly the quantity $y'_1 - y'_2$ and therefore by equation (13) determines Δ.

The quantity $\frac{1}{2}(y'_1 + y'_2)$ represents the angular distance from the rotation axis of the telescope to the middle point of the line joining the two images in the field of the telescope, and if ordinary care is bestowed upon the adjustment and pointing of the telescope, this quantity can never exceed a very few minutes of arc. It, therefore, appears from (12) and (13) that both $\sin (A_1 + A_2 + \eta)$ and $\sin \left\{ A_1 - A_2 + \frac{\Delta}{2} \right\}$ are small quantities, and since approximately $A_2 = 120^\circ$, $A_1 = 240^\circ$, $A_1 + A_2 + \eta = 0^\circ$, $A_1 - A_2 + \frac{\Delta}{2} = 180^\circ$, we may substitute arcs for sines, and writing in place of $y'_1 - y'_2$ the distance between the images of the stars as measured with the micrometer, which will be represented by d', we have

$$\Delta = 360^\circ - 2(A_1 - A_2) \pm d' \sec Y + K' \qquad (15)$$

in which $Y = A_1 + A_2 + \eta$, and $\sec Y$ may in every case be put equal to unity without the introduction of sensible error.

The reel contains three mirrors, any pair of which may be used to reflect images of the stars into the field of view of the telescope, and when so employed they will furnish an equation of the form (15). If each pair of mirrors be so used and the mean of the resulting equations be taken we shall obtain

$$\Delta = 120^\circ \pm d + K \qquad (16)$$

which is the formula that has been used for the reduction of all the present series of observations.

The value of K in this expression must be the mean of the several values of K' given by (14), but since this expression is somewhat complicated it will be well to consider the method of adjusting the instrument and determining its errors before deriving a definitive expression for K.

Determination of the Parallel Since for thc measurement of d the micrometer threads must be placed parallel to the axis of z, a process analogous to the determination of the parallel in the case of an ordinary filar micrometer becomes necessary. To effect this the images of the stars S_1, S_2 were made to cross the field of view by slowly revolving the reel about its axis, and by trial a position of the thread was found at which the stars would run along the thread over the whole width of the field of view. When the micrometer box is rotated 90° from this position the threads are obviously parallel to the axis of the reel. In the early part of the work the parallel was determined on every night. Later, when it had become evident that this reading was very constant, determinations were made less frequently. In every determination of the parallel both of the stars S_1, S_2 were observed and the mean result adopted for the reading of the parallel, in order to eliminate from this quantity the effect of mal-adjustment and erroneous pointing of the instrument.

A rough check upon the setting of the threads was obtained at every measurement of a pair of stars by noting that when the telescope tube was slightly rotated in the cradle the stars were displaced along lines parallel to the micrometer threads. This rotation of the tube also serves as a check against observing by accident two stars reflected from the same mirror instead of the pair desired, since stars reflected from the same mirror will be displaced in the same direction by a rotation of the tube, but in opposite directions if they are reflected from opposite mirrors.

THE INSTRUMENTAL ERRORS OF ADJUSTMENT, ξ, η, θ, i, h, c.

The quantities ξ, η, θ depend upon the position into which the telescope is brought for the observation of a pair of stars, and therefore change with each setting of the instrument, while i, h and c are more strictly errors of adjustment of a semi-permanent character, $90° + i$ being the angle between the axis of the reel and the rotation axis of the tube; $90° - h$ the angle between the axis of the reel and the normal to any one of the mirrors; and c the collimation of the transverse micrometer thread referred to the rotation axis of the tube. If the telescope be so pointed that the reflected images of a pair of stars are brought into the field of view and the telescope tube then be rotated 180° in its cradle, the same pair of stars will again be visible. It is evident that this change of position does not affect or η, but that θ becomes $180° + \theta$, and that the other quantities are respectively transformed into $-i$, $-h$, $-c$. It is therefore necessary to distinguish between these two positions of the tube, and they will be designated respectively as *Cord Up*, and *Cord Down*, the reference being to the position of the endless cord passing around one end of the reel.

To the quantities above enumerated one other constant, f, should be added. The reel being a comparatively heavy body, it may be presumed that its supports will

bend slightly under its weight, and that the angle i will vary with the position of the instrument. I therefore put

$$i = i_0 - f \sin z \quad \textit{Cord Up.} \qquad -i = -i_0 - f \sin z \quad \textit{Cord Down.}$$

To determine the relations which subsist among these quantities we revert to equations (9) and (10), and introducing rectangular coördinates find by neglecting terms of the second order,

$$z'_1 = 2h_1 \cos(a_1 - A_1) + (\xi + i) \cos\frac{\varDelta}{2} - \theta \sin\frac{\varDelta}{2}$$

The plane zy in which these coördinates are measured may be made to coincide with the plane of the micrometer threads by revolving the primitive system of coördinates about the axis of y through the angle $-i$, and if after this rotation the origin be displaced parallel to the axis of z through a distance c, we shall have the following expression for the position of the star's image, in which the z coördinate is measured from the transverse micrometer thread, positive toward the apparent upper half of the field.

$$z'_1 = 2h_1 \cos(a_1 - A_1) + (\xi + i) \cos\frac{\varDelta}{2} - \theta \sin\frac{\varDelta}{2} - i - c \tag{17}$$

For the determination of the instrumental constants I have made use of reflection observations analagous to meridian circle observations of the nadir. One of the mirrors being brought by rotation of the reel into a position in which its normal is approximately parallel to the axis of the telescope, a reflected image of the micrometer threads is formed in the field of view, and the distance between the transverse thread and its image is measured with the micrometer. It is evident that save for the effect of flexure this distance is independent of the direction in which the telescope is pointed, and since $a_1 = A_1$ and $\frac{\varDelta}{2} = 180°$, we have

$$z'_1 = 2(+h_1 - i_0 + f \sin z) - c \qquad \textit{Cord Up.}$$
$$z'_1 = 2(-h_1 + i_0 + f \sin z) + c \qquad \textit{Cord Down.}$$

Let the micrometer box be set at the position angle for which the threads are parallel to the axis of y, denote by R_0 the reading of the screw at which the fixed and movable threads are in coincidence, and denote by R_1 and R_2 respectively the readings when the movable thread is brought into coincidence with the reflected image of the fixed thread *Cord Up* and *Cord Down;* we shall have

$$(R_1 + R_2 - 2R_0)r = 4(h_1 - i_0) - 2c$$
$$(R_1 - R_2)r = 4f \sin z \tag{18}$$

where r denotes the value of a revolution of the screw.

The latter equation gives immediately a determination of f, and this may be made independently from each mirror. The following determination, made on Oct, 8, 1890, may be cited as an example of the degree of accordance to be expected among the individual determinations:

Mirror.	1	2	3
f	+78″	+66″	+51″

The adopted mean results for the several mirrors are 71′, 59′, 55′ respectively.

If the telescope be directed to a terrestrial mark the value of c may be determined from micrometer readings upon the mark made, *Cord Up* and *Cord Down*, or the longitudinal screw which moves the micrometer box may be employed to so adjust the threads that c shall become zero. I have employed the latter method, and I therefore put $c = 0$ in equations (17) and (18).

Observations by reflection from each mirror furnish a determination of the difference $h - i_0$, and a single additional equation involving these quantities will suffice for their determination.

Such an equation may be obtained as follows: Let the telescope be directed approximately to the middle point of the arc Δ joining a pair of stars whose distance apart does not differ greatly from 120°. Assuming $c = 0$, and writing out for each star the equation corresponding to (17), we have

$$z'_1 = h_1 + \tfrac{1}{2}(\xi - i) - \theta \sin 60°$$
$$z'_2 = h_2 + \tfrac{1}{2}(\xi - i) + \theta \sin 60°$$

Putting $\zeta = \tfrac{1}{2}(z_1^1 + z_2^1)$, we obtain

$$\left.\begin{aligned} 2\zeta' &= + h_1 + h_2 + \xi - i_0 + f \sin z \qquad \textit{Cord Up.} \\ 2\zeta'' &= - h_1 - h_2 + \xi + i_0 + f \sin z \qquad \textit{Cord Down.} \end{aligned}\right\} \quad (19)$$

Expressing the values of ζ in terms of the micrometer readings as above and subtracting,

$$2(R' + R'' - 2R_0)\,r = h_1 + h_2 - i_0 \qquad (20)$$

and a similar equation may be obtained from each pair of mirrors.

If we represent the absolute term of equation (20) by n_3, and of (18) by n', with a corresponding notation for the similar equations resulting from the other mirrors, we shall have the following group of equations from which to determine the values of i_0, h_1, h_2, h_3:

$$\begin{aligned} h_1 - i_0 &= n' \qquad & h_2 + h_3 - i_0 &= n_1 \\ h_2 - i_0 &= n'' \qquad & h_1 + h_3 - i_0 &= n_2 \\ h_3 - i_0 &= n''' \qquad & h_2 + h_1 - i_0 &= n_3 \end{aligned}$$

If from these equations normal equations be formed in the customary manner, and an algebraic solution for the values of the unknowns be made, they will be found to be as follows:

$$\left.\begin{aligned} 2h_1 &= (n_2 - n'') + (n_3 - n''') \\ 2h_2 &= (n_1 - n') + (n_3 - n''') \\ 2h_3 &= (n_1 - n') + (n_2 - n'') \\ 3i_0 &= (n_1 + n_2 + n_3) - 2(n' + n'' + n''') \end{aligned}\right\} \quad (21)$$

These equations are so readily applied to the derivation of numerical values that I have uniformly employed them for the determination of i_0 and h, although the absolute terms represented by the accents are much better determined than those to which subscripts are affixed, and strictly should receive greater weight in the formation of the normal equations. A table of observed values of these instrumental constants may be found at p. 24.

The equations already derived serve as a basis for the determination of the quantities ξ, η, θ. which depend upon the position of the telescope relative to the stars to be observed. Applying equation (17) to each star of a pair under observation, we have, when Δ approximately equals 120°,

$$\begin{aligned} z'_1 &= 2h_1 \cos(a_1 - A_1) + (\xi - i) \cos\frac{\Delta}{2} - \theta \sin\frac{\Delta}{2} \\ z'_2 &= 2h_2 \cos(a_2 - A_2) + (\xi - i) \cos\frac{\Delta}{2} + \theta \sin\frac{\Delta}{2} \end{aligned} \tag{22}$$

from which it appears that if the telescope tube be turned in its cradle until the line joining the star images is perpendicular to the micrometer threads,, *i. e.*, $z'_1 = z'_2$, θ will very approximately equal $h_1 - h_2$. If each pair of mirrors be successively employed for the observation of the stars, and the readings T', T'', T''' of the tube circle (P circle) at which $z'_1 = z'_2$ be noted, we shall have

$$\theta = 0 \qquad \text{when} \qquad T = \tfrac{1}{3}(T' + T'' + T''')$$

since $(h_1 - h_2) + (h_2 - h_3) + (h_3 - h_1)$ is necessarily zero. The value of T thus determined has been employed only for an approximate setting of the tube in order to find the stars. In the actual measurement of the distance between the images in the field of view the tube was rotated in its cradle until the line joining the images was by estimation parallel with the transverse micrometer thread, in which position I assume

$$\theta = \tfrac{1}{2}(h_1 - h_2) \operatorname{cosec}\frac{\Delta}{2}$$

From equations (19) we have

$$\zeta' + \zeta'' = (R' - R'')r = \xi + f \sin z \tag{23}$$

which determines ξ, since f is a known quantity. If by trial a pointing of the telescope be found at which a rotation of the tube through 180° will leave $R' = R''$, we shall have $\xi = -f \sin z$.

The same rotation of the tube in its cradle may also be used to test the magnitude of η, although an accurate pointing in this coördinate is of small consequence, since it does not enter into the expression for K.

We have now to obtain a definitive expression for the correction K, required by the measured distances, and due to the combined effect of the quantities represented by h, i. f, θ and ξ, and as a preliminary to its derivation a brief statement of the methods of observation is required. The index corrections of the hour, declination and P circles were always known with a sufficient degree of approximation to secure a ready finding of the stars. After the images had been brought into the field of view by the rough setting, the slow motion about the polar axis was employed to bring the middle part of the arc joining the stars near to the fixed micrometer thread; the reel was then rotated so as to bring one of the stars up to the fixed thread, and the movable micrometer thread was brought up to the other star. A red glass screen placed between the micrometer threads and the incandescent electric

lamp which illuminated them was then withdrawn and the transverse thread, hitherto invisible appeared faintly illuminated; by means of the slow motion in declination the stars were brought near to the thread, and by the slow motion of the tube it was rotated until the line joining the stars was parallel to the thread. The glass screen being replaced, the transverse thread became invisible, the micrometer measures were commenced and two or three bisections of the images furnished by each pair of mirrors were made. The telescope was then rotated 180° in its cradle, the movable thread brought to the opposite side of the fixed thread in order to eliminate the coincidence of the threads, the telescope again adjusted as above described and a similar set of measures with each pair of mirrors was made in the inverse order, to eliminate any progressive change in the angles between the mirrors. In many cases the tube was used in one position only, *e. g.*, Cord Up, but in every measurement of a pair of stars each pair of mirrors was employed and the coincidence of the micrometer threads eliminated.

The transverse micrometer thread did not pass through the rotation axis of the tube, but was distant from it very approximately one minute of arc, the point of the field through which the axis passed appearing to the observer to be between the transverse thread and the cord governing the reel. The final setting of the telescope in declination was so made that the stars appeared to lie between the transverse thread and the cord at an estimated distance from the thread of 1′, *i. e.*, $z'_1 = z'_2 = 0$. We have, therefore, the following relations among the instrumental errors which are assumed to be satisfied at the instant of observation:

$$h_1 + h_2 + \xi - i = 0$$

$$2\theta \sin\frac{\Delta}{2} + h_2 - h_1 = 0 \qquad (24)$$

By means of these equations we eliminate ξ and θ from equations (14), and find

$$K' = \sqrt{3}\left\{ i(h_1 + h_2 - i) - \tfrac{1}{6}(h_1 - h_2)^2 \right\} \qquad (25)$$

Taking the mean of the values of K' for the several angles of the reel, there results

$$K = \sqrt{3}\left\{ \frac{i}{3}(2\Sigma h - 3i) - \tfrac{1}{18}\Sigma(h - h)^2 \right\} \qquad (26)$$

where the first summation symbol extends over the three mirrors, and the last one over the three pairs of mirrors constituting the angles of the reel. If $h - i$ is very small, as is usually the case, we may write after introducing the flexure term,

$$K = \sqrt{3}\, i_0^2 + \sqrt{3} f^2 \sin^2 z \pm 2 i_0 f \sin z$$

Since the last term in this expression is eliminated from the mean of an observation *Cord Up* and *Cord Down*, I have usually neglected it.

I have adopted for f as a mean value, one minute of arc, and have computed for each pair of stars the value of $\sqrt{3} f^2 \sin^2 z$, using for z the zenith distance

of the middle point of the arc joining the stars at the average hour angle at which they were observed. With the exception of this term the expression for K is constant for all pairs of stars so long as the instrumental constants i_0, h_1, h_2, h_3, remain unchanged, and since the observed values of these quantities for considerable periods of time show no variations greater than can fairly be attributed to error in the determinations, I have employed during such intervals a constant value of K corresponding to the average values of the instrumental constants. A table of observed values of these constants follows.

OBSERVED VALUES OF THE INSTRUMENTAL CONSTANTS.

Date.	*Obs'r.*	i_0	h_1	h_2	h_3	*Date.*	*Obs'r.*	i_0	h_1	h_2	h_3
1890-91		′	′	′	′	1891-'92		′	′	′	′
Oct. 18	C.	−3.9	−3.7	−3.9	−3.6	April 11	F.	+1.6	+0.9	−0.3	+0.3
20	C.	3.5	3.7	3.5	3.8	15	F.	+2.1	+0.7	−0.1	0.0
21	F.	3.1	3.4	3.2	3.5	18[1]	C.	+0.7	−0.2	−1.0	−0.5
22	C.	3.0	3.2	2.9	3.3	22	C.	+0.8	+0.2	−0.8	−0.6
23	F.	3.7	4.0	3.9	4.0	26	C.	+1.8	+0.6	−0.5	−0.1
24	C.	3.4	3.6	3.3	3.6	May 2[2]	C.	+1.6	+0.4	−0.5	−0.1
31	C.	3.4	3.7	3.5	3.6	2	C.	−0.6	−0.1	−1.3	−0.6
Nov. 4	C.	3.8	3.6	3.6	3.8	4[3]	C.	−2.1	−1.7	−3.3	−2.2
5	F.	3.3	3.4	3.2	3.6	5	C.	−0.2	+0.4	−0.8	−0.1
10	C.	3.7	3.8	3.6	3.8	7	C	+0.7	+1.2	−0.0	+0.6
11	F.	3.6	3.4	3.4	3.8	11	C.	−0.1	+0.6	−0.4	+0.0
12	C.	3.6	3.7	3.5	3.7	26	C.	−0.0	+0.7	−0.1	+0.1
18	C.	3.9	3.7	3.6	3.8	June 11	C.	−0.3	+0.8	−0.5	+0.1
19	F.	3.7	3.7	3.5	3.0	23	F.	−0.8	+0.6	−0.3	−0.2
21	F.	2.9	3.3	3.3	3.5	Aug. 2	C.	−1.4	+0.1	−1.0	−0.5
23	F.	3.8	3.7	3.7	3.6	28	C.	−0.4	−0.5	−0.6	+0.2
25	F.	−3.3	−3.6	−3.7	−3.5	Sept. 8	C.	−0.4	+0.6	−0.6	+0.1
March 10	C.	+1.9	+1.0	+1.1	+0.7	Oct. 15	C.	−0.4	+1.0	−0.3	+0.6
11	F.	+1.7	+1.0	+1.3	+0.4	Dec. 11	C.	−1.3	0.0	−1.2	−0.4
15	C.	+1.9	+0.7	−0.1	+0.4	Feb. 25[4]	C.	−2.1	−2.1	−2.7	−1.9
April 4	C.	+1.3	+0.7	−0.1	+0.1	Mar. 23	C.	−1.1	+0.1	−1.0	−0.2
7	F.	+1.4	+0.7	−0.1	−0.1	June 27	C.	−0.8	+0.8	−0.4	+0.3

These constants furnish the following determinations of K_0, *i. e.*, that part of K which is independent of the zenith distance:

Date.	K_0	*Date.*	K_0	*Date.*	K_0
	″		″		″
1890 Oct. 18	+0.22	1890 Nov. 23	+0.42	1891 May 5	0.00
20	.42	25	+ .40	7	− .01
21	.36	1891 March 10	− .02	11	.01
22	.29	11	.00	26	.00
23	.48	15	.08	June 11	.01
24	.38	April 4	.04	23	− .00
26	.40	7	.06	Aug. 2	+ .03
Nov. 4	.42	11	.06	28	+ .01
5	.36	15	.11	Sept. 8	− .01
10	.42	18	.04	Oct. 15	− .02
11	.38	22	.05	Dec. 11	− .01
12	.42	26	.10	1892 Feb. 25	+ .16
18	.42	May 2	− .09	March 23	− .03
19	.36	2	+ .01	June 27	− .03
21	.36	4	+ .18(?)		

THE MICROMETER.

The micrometer employed for all observations, both with the prism and the reel, was that constructed by Alvan Clark & Sons for the 40 *cm.* equatorial telescope of this observatory. A description of the micrometer is contained in Vol. I, Publications W. O., and to that description I have only to add that the oil lamp formerly employed to illuminate the threads was replaced by an incandescent lamp fed from a bichromate of soda battery and provided with a variable resistance in the circuit, by means of which the intensity of the illumination could be varied at will. Since the date of that description I have added to the micrometer a clamp by which it may be secured at any reading of the position circle.

The eyepieces which have been employed are as follows:

No.	Field.	Power.	Construction.	Maker.
	′			
I.	30.5	75	Ramsden.	Clark.
III.	14.7	167	Ramsden.	Clark.
V.	20.2	124	Steinheil.	Kahler.

No. I has been employed only in the observation of transits for the determination of the value of a revolution of the screw and in the reflection observations for the determination of instrumental constants. Nos. III and V have been about equally employed in the observation of pairs of stars. The field lens of eyepiece V has a deep scratch near its central part which has caused some annoyance, since when the image of a star is formed near the scratch the image at times appears double or even triple. The few observstions in which this occurs are specially noted in the Tabulated Results of the Observations.

Part II of Vol. VI., Publications W. O., contains an account of an investigation of the errors of the micrometer screw, and in so far as that investigation relates to periodic errors I adopt its results and assume these errors to be entirely inappreciable. I have, however, rediscussed the observations for progressive error which were made upon the measuring engine of the Transit of Venus Commission at the U. S. Naval Observatory, and have supplemented them by an entirely new series of observations made with the Repsold meridian circle of this observatory, as follows:

In January, 1891 the telescope was detached from the declination axis, and without disturbing its focal adjustment it was firmly mounted upon the south collimator

pier, with its line of sight horizontal and directed toward the meridian circle. The micrometer was attached to the telescope and rotated in position angle until its screw was vertical, in which position it was clamped, and the angular distance moved over by the threads when the screw was turned through successive intervals of eleven revolutions, = 5′ 1″, was measured with the meridian circle. The observing programme was so arranged that only those divisions of the circle whose errors had been determined were employed for the microscope readings, and any error in the assumed value of a revolution of the declination micrometer was nearly, if not quite, eliminated from the final result for errors of the screw under investigation. Observations of this character were made upon seven days, between Jan. 21 and Jan. 28 inclusive, and an equal number of these observations were made with the micrometer screw placed Head Up and Head Down. After the observations of Jan. 21 and Jan. 24, the microscopes of the meridian circle were shifted so as to bring new sets of lines under them. The combined effect of these changes is to make the adopted value of the angle moved over by the micrometer thread in passing from the reading, 50.0 *rev.* to any other assumed reading depend upon the mean of the division corrections to twenty-four lines of the circle.

The daily results for these angles, together with the adopted mean values are as follows.

VALUE OF A REVOLUTION AT DIFFERENT PARTS OF THE SCREW.

Revolutions.	Jan. 21.	Jan. 22.	Jan. 23.	Jan. 24.	Jan. 26.	Jan. 27.	Jan. 28	Mean.	
	″	″	″	″	″	″	″	′	″
50— 6	4.95	4 42	....	....	5.60	4 75	4.15	20	4.72
50—17	....	....	3.80	2.80	3.75	3.95	3.15	15	3.49
50—28	2.65	2.78	2.90	2 20	2.55	2.85	2.55	10	2.66
50—39	....	....	1.95	1.20	1.45	1.80	1.00	5	1.48
50—61	....	....	1.65	1.55	1 95	1 90	1 95	5	1.80
50—72	4.10	3.68	3.35	2 85	3.85	4.05	3.75	10	3 66
50—83	....	....	5.25	4 80	5.50	5.55	5.45	15	5 81
50—94	7.70	6.87	....	....	6.85	7.00	7.35	20	7.07

A comparison of corresponding numbers in the last column of this table shows clearly that the pitch of the screw is not uniform, and if it be desired to use a constant value of a revolution of the screw, corrections must be applied to its readings in order to compensate the progressive inequality here indicated. I have adopted as the mean value of a revolution of the screw, $r = 27''.417$, and have derived corresponding values of the correction, σ, at intervals of eleven revolutions throughou the whole range of tne screw.

The results thus obtained show a most gratifying agreement with those obtained in 1887 from the Washington measuring engine, after the correction of an obvious error of sign in a part of the latter determinatious, and I have therefore included both sets of data in a single graphical adjustment. Adopted values of the corrections thus obtained are given in the following table, together with the excess of the adjusted values over those directly observed. Observed values of the correction derived from the measuring engine are indicated by the letter E, those from the meridian circle by M, and the unit in which each is expressed is a thousandth part of a revolution of the screw.

CORRECTIONS FOR PROGRESSIVE ERROR OF SCREW.

Rev.	σ	*E.*	*M*	Rev.	σ	*E.*	*M*
	r				*r*		
5	+0.061	− 2	+ 2	50	0.000	0	0
10	.057	− 2	......	55	+ .002	0	....
15	.049	0	− 2	60	.006	− 2	− 1
20	.037	+ 5	....	65	.011	+ 3	......
25	.025	+ 1	......	70	.015	0	− 2
30	.014	+ 1	0	75	.018	0	......
35	.005	+ 2	......	80	.021	+10	....
40	+ .001	− 1	− 1	85	.023	− 3	+ 2
45	− .001	0	....	90	.025	0	......
50	.000	0	0	95	+ .027	+ 4	0

These corrections have not been applied to the readings of the micrometer, but all observations have been reduced as if the screw were of uniform pitch, and in lieu of σ, corrections to the resulting distances have been taken from the following table, whose argument is the mean reading of the head of the screw for any set of pointings. The correction to the measured distance is given by the formula:

$\Delta d = \rho_1 + \rho_2$ *Double Distances.*

$\Delta d = 2\rho$ *Single Distances.*

R	ρ_1	R	ρ_2
	"		"
20	−0.51	50	0 00
25	.34	55	+ .03
30	.19	60	.08
35	.07	65	.14
40	− .03	70	.21
45	+ .01	75	.25
50	.00	80	+ .29

The observations with the meridian circle furnish an excellent determination of the value of a revolution of the micrometer screw, which may properly be employed for the reduction of observations made with the prism apparatus, since the distance of the micrometer threads from the objective was the same as that at which the star observations were made. I have, nevertheless, made an independent determination of the value of a revolution of the screw, from transits of stars in approximately 30° declination, observed by reflection from the mirrors. The resulting values from observations made between May, 1890, and July, 1891, upon nine nights by Mr. A. S. Flint, and upon seven nights by myself, at temperatures ranging from + 28° F. to + 77° F., are as follows:

Obsr., G. C. C.,	27".417 ± 0.006	Temp. 41° F.
Obsr., A. S. F.,	27 .401 ± 0.009	Temp. 59
Mean,	27 .412 ± 0.004	Temp. 47

In the reduction of these observations the systematic corrections given above were employed, and the results are, therefore, directly comparable with the value of a revolution obtained from the meridian circle. The difference between the values furnished by the two methods is but slightly in excess of the probable error of the value derived from transits, and the agreement is therefore satisfactory. From the manner in which the value furnished by the meridian circle was obtained, its probable error must be assumed to be zero, the entire uncertainty of the determination being thrown upon the correction, σ, to the readings of the screw. From the 44 residuals furnished by the table at p. 27 I obtain as the probable error of a single determination of σ, ± 0".26, and for the average probable error of a mean value, ± 0".12. The probable error of an adopted correction, p. 28, must be less than this quantity, since it results from an adjustment into which a considerable body of additional data has been introduced. Estimating the probable error of an adjusted value of σ at 0".07 (See the residuals in the table), I assume as the definitive value of a revolution of the screw, 27".417, with a probable error of zero; and that part of the prob-

able error of a distance measured by the method of "double distances" which arises from a defective knowledge of the screw will then be

$$r = \pm 0''.07 \div \sqrt{2} = \pm 0''.05$$

This value will hold equally for large and small distances, unless the distance be so small that the effect of progressive error may be considered insensible, in which case this component of the probable error of a distance will be greatly diminished.

FOCAL LENGTH OF THE OBJECTIVE.

As an additional method of investigating the value of a revolution of the screw, I have determined the focal length of the objective by the method of Bessel. Observations for this purpose were made on four days in February, 1891, and from the note books employed on these dates I extract the following memoranda:

"The marks placed at the conjugate foci of the objective were a plumb line of copper wire 0.01 inches in diameter, and an exposed photographic plate, upon which fine lines had been ruled. Upon placing a bull's eye lamp behind the plate these lines appeared as bright threads. Eyepiece I placed adjacent to the plumb line was employed for setting the objective. To measure the distance between the marks a distance of nine decimeters was transferred thirteen times from a bar marked 'U. S. Standard Metre, No. 9, Standard at 67°.2 Fahr.,' to the back of a steel tape, and the several lines thus produced were marked 0 to 13 inclusive. Between 12 and 13 two lines were drawn at distances of one and two decimeters respectively from line 13. All of the transferring was done with an apparatus designed for the purpose and furnished with the bar. I estimate the probable error of transferring a single section, 9 decimeters, at approximately 0.05 *mm.* During the tranfer the tape was stretched along a flat surface by a weight of about 20 lbs. attached at one of its ends. The temperatures during the transfer were included between 66 and 68° Fahr."

"In measuring the distance between the focal points the tape was hung in a single loop reaching from the plumb line to the photographic plate, and was stretched by the same weight employed during the transfer of the marks from the standard bar. The plumb line terminals being adjustable in position, the steel tape was so placed that the line 1 was exactly under the face of the photographic plate 63 *mm* below the marks, and the plumb line then made to swing opposite line 12. The distance between these lines at the time they were drawn being 9900 *mm.*, the distance between the conjugate foci of the lens will be this quantity plus corrections for stretch of tape due to its own weight, for temperature and for the catenary."

"The objective was supported in a wooden frame made to slide along a plank adjusted in position between the end marks. To determine the position of the objective in which the foci coincided with the marks above described, three independent settings were made by each of two observers, C. and F. The distance moved over by the objective was measured with an engineer's standard meter scale.

After the corrections above named are applied, the several results for the focal length of the objective plus one fourth of the distance between the principal points, are as follows:

Date.	Temp.	F.
1891 Feb. 7	52° F.	2385.8 *mm.*
10	48	2385.4
11	46	2385 8
12	46	2385.5

"To determine the distance between the principal points of the objective, one of microscopes of the meridian circle was mounted in a horizontal position on a sliding carriage in front of a photographic plate upon which lines had been ruled. A metric scale was attached to the carriage, parallel with the direction of its motion, and the readings of this scale in a telescope placed opposite it were employed to determine the position and motion of the carriage when the microscope was focused upon the ruled lines seen alternately through the objective and without its interposition. The mean result for the distance between the principal points, found by three observers, is 6.54 *mm.* ± 0.05 *mm*, and subtracting one fourth of this from the mean value of F we obtain as the definitive result for the focal length of the objective, 2384.0 *mm.*, with an estimated probable error of ± 0.15 *mm.*"

From the observations made in 1887 with the Washington measuring engine, reduced with a value of one division of its scale, kindly communicated to me by Prof. William Harkness, I find for the linear pitch of the micrometer screw at 50 rev., 0.31748 *mm.*, with an estimated probable error of 2 units of the last decimal place. This number, together with the value of the focal length of the objective found above furnished 27″.468 as the value of a revolution of the screw when the micrometer threads are placed at the focus of the objective. A sufficient explanation of the difference, 0″.051, between the adopted value of a revolution of the screw and the value here determined may be found in the assumption that the mirrors from which the star images were reflected were pinched by their adjusting screws so as to produce curved surfaces. Using the adopted value of a revolution of the screw and its linear pitch to compute the focal length of the combination, mirror + objective, I find 2388.5 *mm.* The excess of 4.5 *mm* above the measured length indicates a radius of 5 *km* for the osculating sphere corresponding to the mirrors. While no great weight can be attached to this number as a determination of the radius of curvature of the mirrors, it appears to indicate that the amount of curvature demanded in explanation of the discordance between the values of a revolution of the screw is not excessive.

Since this apparatus is to be employed for an investigation of the aberration and refraction, it will be necessary to consider their effect and the effect of proper motion upon the angular distance, Δ, between two stars. I take up first the aberration.

EFFECT OF ABERRATION UPON THE APPARENT DISTANCE BETWEEN TWO STARS.

If we designate as the "goal" that point of the celestial sphere toward which the earth's motion is at any instant directed, and represent by p the angular distance of any star from the "goal," the effect of aberration will be to displace the star toward the "goal" by an amount given by the equation

$$a = \frac{w}{V} \sin p \tag{28}$$

where V represents the velocity of light, and w the velocity of the earth in its orbit. If in the spherical triangle formed by the "goal" and any two stars, we represent the angles at the stars by Q' and Q'', the arc joining the stars by $\varDelta$, the angular distance of the stars from the "goal" by p', p'', and the arc joining the goal to the middle point of $\varDelta$ by p, we shall obtain as an expression of the amount by which the aberration alters the length of $\varDelta$,

$$\begin{aligned} d\varDelta &= -\frac{w}{V} (\sin p' \cos Q' + \sin p'' \cos Q'') \\ &= -\frac{w}{V} 2 \sin \frac{\varDelta}{2} \cos p \end{aligned} \tag{29}$$

The variable part of this expression, $w \cos p$, admits of development as follows: Representing by λ, β, L, O, the longitude and latitude of the middle point of $\varDelta$ and of the "goal" respectively, we obtain from the spherical triangle formed by these two points and the pole of the ecliptic,

$$\cos p = \cos \beta \cos (\lambda - L) \tag{30}$$

If we represent by $90° - \gamma$ the angle between the direction of the earth's motion and the prolongation of its radius vector, and by s the longitude of the sun, we have

$$L = s - \gamma - 90°$$

and from the properties of the ellipse,

$$\begin{aligned} \sin \gamma &= e \sin v - \tfrac{1}{4} e^2 \sin 2v + \ldots . \\ \cos \gamma &= 1 - \tfrac{1}{2} e^2 \sin^2 v + \ldots . \end{aligned} \tag{31}$$

where e and v represent respectively the eccentricity and the true anomaly. The velocity of the earth in its orbit is given in terms of the radius vector by the familiar relation,

$$w = k' \sqrt{\frac{2}{r} - 1}$$

which is equivalent to

$$w = k' \left\{ 1 + e \cos v + \tfrac{1}{4} e^2 (1 + \sin^2 v) + \ldots . \right\} \tag{32}$$

If by means of these equations w and L be eliminated from the expression for $d\Delta$, it is transformed into

$$d\Delta = \frac{k'}{V}\left\{1+\frac{e^2}{2}\right\} 2 \sin\frac{\Delta}{2} \cos\beta \sin(\lambda - s) + \frac{k'e}{V} 2 \sin\frac{\Delta}{2} \cos\beta \sin(\lambda + v - s) \qquad (33)$$

Since $s - v$ is the longitude of the sun's perigee the last term in this expression is constant, and denotes a small permanent change in Δ produced by the aberration. The coefficient of the first term is commonly called the constant of aberration, and denoting it by k, we have as the complete expression for the varying effect of aberration upon the apparent distance between two stars,

$$\begin{aligned} f &= 2\,k \sin\frac{\Delta}{2} \cos\beta \\ d\Delta &= f \sin(\lambda - s) \end{aligned} \qquad (34)$$

The value of the constant coefficient f has been computed for each pair of stars included in the observing program, with the assumed value, $k = 20''.448$, and its logarithm is given in the table of reduction elements.

Diurnal Aberration. We obtain immediately from the preceding formulæ the effect of diurnal aberration by substituting for the "goal" the east point of the horizon, and for w the linear velocity due to the earth's rotation, which is given by the expression,

$$w = \frac{2\pi}{T}(a\rho + h)\cos\varphi'$$

where h is the elevation above the sea and $T = 86164$ is the number of mean solar seconds in a sidereal day. Putting $w \mid V = \varkappa$, and representing by P the distance from the middle point of the arc Δ to the east point of the horizon, we obtain

$$d\Delta = -\varkappa\, 2 \sin\frac{\Delta}{2} \cos P = +0''.468 \sin\frac{\Delta}{2} \cos\delta \sin t \qquad (35)$$

in which the numerical coefficient corresponds to the position of the Washburn Observatory, and δ and t are the declination and hour angle of the middle point of the arc Δ at the instant of observation.

Corrections for diurnal aberration have not been applied to the individual observations, but are applied to the resulting mean values of Δ derived from all of the observations of each pair.

Effect of Proper Motion upon Δ. If we represent by $\mu_1, \mu_2, \mu'_1, \mu'_2$ the proper motions of two stars in right ascension and declination, and employ the same subscripts in connection with the coördinates of the stars, we may obtain by differentiating the relations furnished by the spherical triangle formed by the two stars and the pole:

$$-\sin\Delta\, d\,\Delta = \sin\Delta \cos Q_1\,(\tau\mu'_1) + \sin\Delta \cos Q_2\,(\tau\mu'_2) - \cos\delta_1 \cos\delta_2 \sin(\alpha_2 - \alpha_1)\,\tau\,(\mu_2 - \mu_1)$$

where Δ denotes the side of the triangle joining the two stars; Q_1, Q_2 are the angles

adjacent to this side and τ denotes the time interval during which the effect of proper motion accumulates. We have rigorously

$$\begin{aligned} \cot Q_1 &= \sin \frac{\Delta}{2} \tan \delta_0 \operatorname{cosec} P + \cos \frac{\Delta}{2} \cot P \\ \cot Q_2 &= \sin \frac{\Delta}{2} \tan \delta_0 \operatorname{cosec} P - \cos \frac{\Delta}{2} \cot P \\ \cos \delta_1 \cos \delta_2 \sin (\alpha_2 - \alpha_1) \operatorname{cosec} \Delta &= \cos \delta_0 \sin P \end{aligned} \tag{36}$$

where δ_0 and P have the same significance as in Fig. C. In place of these I have usually substituted the approximate relations,

$$\begin{aligned} \cos Q_1 &= \sin \frac{\Delta}{2} \tan \delta_0 + \tfrac{1}{2} \cos P \\ \cos Q_2 &= \sin \frac{\Delta}{2} \tan \delta_0 - \tfrac{1}{2} \cos P \end{aligned} \tag{37}$$

$$\frac{d\Delta}{dT} = \cos \delta_0 \sin P (\mu_2 - \mu_1) - \cos Q_1 \, \mu'_1 - \cos Q_2 \, \mu'_2 \tag{38}$$

This differential coefficient represents the annual effect of proper motion upon the angular distance between the stars, and its value for each pair is given under the heading μ in the Table of Reduction Constants.

EFFECT OF REFRACTION UPON THE APPARENT DISTANCE BETWEEN TWO STARS.

The effect of refraction upon the apparent distance between two stars is investigated in most of the text books of spherical astronomy, but none of the solutions there derived are applicable for a precise determination of the effect when the stars are separated by so great an arc as 120°, and it is therefore necessary to derive formulæ for this case. In Figure C let S_1 and S_2 represent stars whose true distances from the zenith, Z, are respectively z_1, z_2, and whose true distance from each other

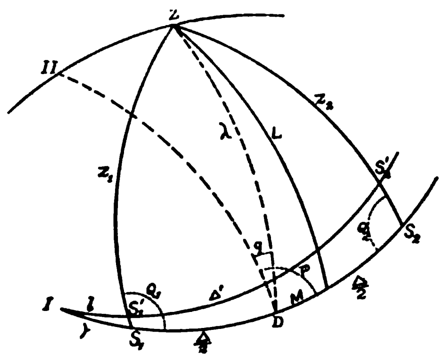


Fig. C.

is Δ. By the effect of refraction these stars are displaced to S'_1 and S'_2, the respective amounts of the refraction being r_1 and r_2. The distance S'_1 S'_2 will be represented by Δ', and it is required to find the quantity $\Delta - \Delta'$.

Let the arcs Δ and Δ' be produced until they intersect at I, and let a spherical perpendicular be let fall from Z upon Δ, and denote the length of this perpendicular by L. Let the distance of the foot of this perpendicular from the middle point of Δ, reckoned positive toward the east, be M. Then from the triangles $I\,S_1\,S'_1$, $I\,S_2\,S'_2$,

$$\begin{aligned} \cos l &= \cos\gamma\,\cos r_1 - \sin\gamma\,\sin r_1\,\cos Q_1 \\ \cos(l+\Delta') &= \cos(\gamma+\Delta)\cos r_2 + \sin(\gamma+\Delta)\sin r_2\,\cos Q_2 \end{aligned} \tag{39}$$

Neglecting terms of the order r^3 and developing in series, these equations become

$$\begin{aligned} l &= \gamma + r_1\cos Q_1 + \frac{r_1^2}{2}\sin^2 Q_1\cot\gamma \\ \Delta' + l &= \Delta + \gamma - r_2\cos Q_2 + \frac{r_2^2}{2}\sin^2 Q_2\cot(\gamma+\Delta) \end{aligned} \tag{40}$$

The second order terms in these expressions do not in practice exceed 0″.05, and it will be sufficient to employ an approximate value of γ in them, and since the observations are made when z_1 and z_2 are nearly equal, we assume this equality and find from the resulting symmetry of the figure,

$$\gamma = 90^\circ - \frac{\Delta}{2} \qquad\qquad \gamma + \Delta = 90^\circ + \frac{\Delta}{2} \tag{41}$$

and since the distinction between r_1 and r_2, Q_1 and Q_2, vanishes when $z_1 = z_2$,

$$\Delta' = \Delta - r_1\cos Q_1 - r_2\cos Q_2 - r^2\sin^2 Q\tan\frac{\Delta}{2} \tag{42}$$

The refraction tables usually determine r as a function of z', the apparent zenith distance, but Bessel has given a table, *Astron. Untersuch. Bd. I.*, by which the true zenith distance may be used, and r found from an equation of the form

$$r = \alpha\tan z$$

Adopting this expression we obtain

$$\begin{aligned} r_1\cos Q_1 &= \alpha_1\tan z_1\cos Q_1 = \alpha_1\tan\left\{\frac{\Delta}{2}+M\right\} \\ r_2'\cos Q_2 &= \alpha_2\tan z_2\cos Q_2 = \alpha_2\tan\left\{\frac{\Delta}{2}-M\right\} \\ r\sin Q &= \alpha\sec z\sin L \quad = \alpha\tan L\sec\frac{\Delta}{2} \end{aligned} \tag{43}$$

Substituting these values in equation (42) it becomes

$$\Delta = \Delta' + \alpha_1\tan\left\{\frac{\Delta}{2}+M\right\} + \alpha_2\tan\left\{\frac{\Delta}{2}-M\right\} + \left(\alpha\sec\frac{\Delta}{2}\tan L\right)^2\tan\frac{\Delta}{2}\sin 1'' \tag{44}$$

If this equation is employed for computing the refractions it will be necessary to determine for each observation not only the auxiliaries, M and L, but also z_1 and z_2 since α_1 and α_2 are functions of the latter quantities. It will be convenient for thi purpose to introduce the Bessel auxiliaries, n, N, *Astron. Untersuch*, *Bd. I.*, p. 196

and to determine the zenith distance and parallatic angle of the middle point of $\varDelta$ by the equations

$$\begin{aligned} \tan\zeta \sin q &= \cot n \operatorname{cosec}(N+\delta_0) \\ \tan\zeta \cos q &= \cot(N+\delta_0) \end{aligned} \qquad (45)$$

Then from the figure, in which Π represents the celestial pole,

$$\begin{aligned} \tan M &= \tan\zeta \cos(P-q) \\ \tan L &= \tan\zeta \sin(P-q) \cos M \end{aligned} \qquad (46)$$

$$\cos z_1 = \cos\left\{\frac{\varDelta}{2}+M\right\}\cos L \qquad \cos z_2 = \cos\left\{\frac{\varDelta}{2}-M\right\}\cos L$$

If it is desired to represent the refraction as a function of the apparent zenith distance, the preceding formulæ may be adapted to this case by substituting for $\varDelta$, Q, M, the apparent quantities, $\varDelta'$, Q', M', and changing the sign of the second order term. The angle P and the right ascension and declination α_0, δ_0, of the point D are known for each pair of stars, and if λ and q are derived from these by means of the Bessel auxiliaries, defined by the relations

$$\begin{aligned} \cos n &= \cos\varphi \sin t \\ \sin N \sin n &= \cos\varphi \cos t \\ \cos N \sin n &= \sin\varphi \end{aligned}$$

(*Astron. Untersuch, Bd I, p 196.*), the equations for the exact determination of the refraction may be put into the following form:

$$t = \text{Sid. Time} - \alpha_0. \quad (\text{Argument for } n \text{ and } N.)$$

$$\begin{aligned} f\sin F &= \cot(N+\delta_0) & \cos z_1 &= \cos L \cos\left\{\frac{\varDelta}{2}+M\right\} \\ f\cos F &= \operatorname{cosec}(N+\delta_0)\cot n & \cos z_2 &= \cos L \cos\left\{\frac{\varDelta}{2}-M\right\} \\ & & R_1 &= \alpha_1 \tan\left\{\frac{\varDelta}{2}+M\right\} \\ \tan M &= f\sin(F+P) & R_2 &= \alpha_2 \tan\left\{\frac{\varDelta}{2}-M\right\} \\ \tan L &= f\cos(F+P)\cos M & R_3 &= \tan\frac{\varDelta}{2}\left\{\alpha f\cos(F+P)\sec\frac{\varDelta}{2}\right\}^2 \sin 1'' \end{aligned} \qquad (47)$$

$$\varDelta - \varDelta' = R_1 + R_2 + R_3$$

The application of (47) to the reduction of a series of observations would be exceedingly laborious, and it is necessary to transform these equations. Their form shows that the effect of the refraction passes through a minimum at or near the time at which $M = 0$. If we denote by R_0 the minimum amount of the refraction, and by T_0 the corresponding sidereal time, it will be possible to represent the refraction at any other neighboring instant T, by an expression of the form

$$R = R_0 + h_0 (T - T_0)^2 \qquad (47^*)$$

where h_0 is a coefficient, constant for each pair of stars, whose value is to be determined.

Neglecting for the moment the second order terms in the refraction, putting $T - T_0 = \tau$, and denoting the first and second derivatives of the several variables with respect to τ by the notation, $f'(R)$, $f''(R)$, $f'(\alpha)$, etc., we obtain the following values, in which M has been put equal to zero.

$$\begin{aligned} f'(R_1 + R_2) &= \tan\frac{\Delta}{2} f'(\alpha_1 + \alpha_2) \\ f''(R_1 + R_2) &= \tan\frac{\Delta}{2} f''(\alpha_1 + \alpha_2) + 4\alpha \sec^2\frac{\Delta}{2} \tan\frac{\Delta}{2} \left\{ f'(M) \right\}^2 + 2 \sec^2\frac{\Delta}{2} f'(M) f'(\alpha_1 - \alpha_2) \end{aligned} \tag{48}$$

Since at the instant when M becomes zero, $\alpha_1 = \alpha_2$, and the diurnal motion causes one of the stars to rise and the other to set, it is apparent that $f'(\alpha_1 + \alpha_2)$ and $f''(\alpha_1 + \alpha_2)$ must be very small quantities, which may be sufficiently taken into account by approximate formulæ. The refraction admits of development in a series of odd powers of $\tan z$, and it will therefore be legitimate to assume

$$\alpha = A - B \tan^2 z$$

and to put

$$\begin{aligned} f'(\alpha) &= -2B \tan z \sec^2 z f'(z) = -2B \sec^2 z \cos\varphi \cos\delta \sin t \\ f''(\alpha) &= -6B \sec^4 z \cos^2\varphi \cos^2\delta \sin^2 t - 2B \sec^2 z \cos\varphi \cos\delta \cos t \end{aligned} \tag{49}$$

where t denotes the hour angle of the star, and must not be confounded with τ. To simplify these expressions, let the following auxiliaries be introduced:

$$\mu = \cos\varphi \cos\delta \cos t \sec z \qquad \nu = \cos\varphi \cos\delta \sin t \sec z \tag{50}$$

where t and z relate to the instant at which the stars have equal altitudes. We shall then have

$$\begin{aligned} f'(\alpha_1 + \alpha_2) &= -2B \sec^2 z (\nu_1 + \nu_2) \\ f'(\alpha_1 - \alpha_2) &= -2B \sec^2 z (\nu_1 - \nu_2) \\ f''(\alpha_1 + \alpha_2) &= -2B \sec^2 z (3\nu_1^2 + 3\nu_2^2 + \mu_1 + \mu_2) \end{aligned} \tag{51}$$

Equations (47) furnish the relation

$$\cos z_1 \cdot \cos\left\{\frac{\Delta}{2} - M\right\} - \cos z_2 \cos\left\{\frac{\Delta}{2} + M\right\} = 0$$

from which is readily obtained

$$f'(M) = \tfrac{1}{2} \tan z \cot\frac{\Delta}{2} f'(z_1 - z_2) = \tfrac{1}{2} \cot\frac{\Delta}{2} (\nu_1 - \nu_2) \tag{52}$$

The differential coefficients contained in (51) and (52) suffice for the development of the refraction in powers of the time reckoned from the instant T_1, at which $M = 0$, and if this development be equated to the second member of equation (47*) and T_0 be put equal to $T_1 + \vartheta$, we shall find from a comparison of the coefficients of like powers of $T - T_1$,

$$\begin{aligned} h_0 &= \tfrac{1}{2} f''(R_1 + R_2) \\ -\vartheta &= f'(R_1 + R_2) \div f''(R_1 + R_2) \end{aligned} \tag{53}$$

Neglecting terms of the order B^2 in the expression for ϑ, it becomes

$$\vartheta = \frac{2\,B}{\alpha} \frac{\sin^2 \frac{\Delta}{2}}{\cos^2 z} \frac{\nu_1 + \nu_2}{(\nu_1 - \nu_2)^2} \tag{54}$$

From Bessel's refraction tables I find with the argument the true zenith distance, $B = 0''.083$, and putting $\Delta = 120°$ and introducing the factor $\frac{206265}{15}$ there results in seconds of time,

$$= \left[4.0134\right] \frac{2B \sec^2 z}{\alpha} \frac{\nu_1 + \nu_2}{(\nu_1 - \nu_2)^2} \tag{55}$$

To simplify the rather complicated expression for h_0 which would result from (53), I put in (51),

$$\nu_2 = -\nu_1, \quad \mu_2 = \mu_1 = \nu_1 \cot t_1, \quad t_1 = 60°,$$

and introduce the auxiliary ψ, defined by the relation

$$\psi = 2\nu\,(1 + 3\sqrt{3}\,\nu) \sin 1'' \tag{56}$$

Values of ψ are given in the following table:

ν	ψ	
0.0	0.00000	
		2
0.5	02	
		4
1.0	06	
		7
1.5	13	
		9
2.0	22	
		12
2.5	34	
		14
3.0	48	
		17
3.5	65	
		19
4.0	0 00084	

Assembling the several differential coefficients which enter into the value of $f''(R_1 + R_2)$, they furnish

$$h_0 = \left\{ \frac{\alpha - 2B \sec^2 z}{\sin \Delta} (\nu_1 - \nu_2)^2 - B \sec^2 z . \psi \right\} \sin 1'' \tag{56}$$

By means of the above formulæ the values of h_0 and ϑ have been computed for each pair of stars observed, and are contained among the reduction constants. The value of h_0 there given is not the h_0 which would result from the above equation, but has been divided by 27.4 in order that the corrections to the minimum value of the refraction may be expressed in parts of a revolution of the micrometer screw.

Resuming the expression for the second order terms derived from equation (42), it appears that, since the effect of these terms is nearly constant for epochs not differ

ing greatly from T_0, they may be united with the expression for the refraction at the instant T_0. Assuming $\Delta = 120°$, we have for this instant,

$$\Delta = \Delta' + \alpha\,(1 + 2\alpha \tan^2 L \sin 1'')\, 2 \tan \frac{\Delta}{2} \tag{58}$$

and denoting by (α) the value of the coefficient in this expression, we find

$$\log\,(\alpha) = \log \alpha + [9.6244]\, \alpha \tan^2 L \tag{59}$$

It is obvious that if it be desired to express the refraction as a function of the apparent zenith distances and apparent Δ of the stars, the same expression for the second order terms may be employed with a change of sign.

Collecting the results above derived, we have the following formulæ for the computation of the refraction:

$$\begin{aligned} \tau &= T - (T_1 + \vartheta) & \qquad \Delta M' &= h_0\, m \\ m &= \frac{2 \sin^2 \frac{1}{2}\tau}{\sin 1''} & \qquad R &= (\alpha)\, \beta^{A'} \gamma^{\lambda'}\, 2 \tan \frac{\Delta}{2} \end{aligned} \tag{60}$$

The quantity $\Delta M'$ is a correction which, when applied to the readings of the micrometer head, reduces them to what they would have been had the refraction not varied from its value at the instant T_0. R, corresponding to the instant T_0, then becomes the complete expression for the effect of refraction upon the observations thus corrected.

The formulæ thus derived represent the refraction as a function of the true distance, Δ, and of the true zenith distance of the stars. The values of α, β, γ, A' λ', have therefore been taken from Bessel's table, which gives these quantities with the argument the true zenith distance. Since this table is derived from that in which the refraction is expressed as a function of the apparent zenith distance by a development which is only approximately correct, I have resorted to the following process to reduce the computed values of R to what they would have been had the development been made in terms of the apparent zenith distance.

From the Pulkowa Refraction Tables, with the argument the apparent zenith dis tances of the stars at the instant T_0, I have derived values of α (called μ in the tables) A and λ. The values of α have been corrected for the effect of second order terms, and have been further corrected by the subtraction of 64 units of the fifth decimal place to take into account the difference in the force of gravity at Pulkowa and Madison. With values of β and γ taken from the same tables, I have computed for each pair of stars the amount of the refraction at assumed temperatures of 0° and 100° F., and a pressure of 29 inches. The refractions corresponding to the same states of the atmosphere were computed from the Bessel elements employed in the reduction, and the values Pulkowa–Bessel tabulated for each pair of stars. Since β is the same for both tables, and A and A' are insensible for all of the observations, these differences will remain constant for all atmospheric pressures, and a correction to reduce the refraction given by the one table to that furnished by the other may

be interpolated from these differences with the temperature as the argument. Corrections derived in this way have been applied to the computed refractions, and are contained in the values of R given in the table of results of observations. The concluded values of Δ are therefore referred to the Pulkowa refraction tables corrected for gravity.

As a control upon the accuracy of the above development and its numerical application, I have employed equations (47) in connection with elements derived from the Pulkowa Tables for the computation of the refraction for one pair of stars, and have also derived from the Bessel Tables, by the method employed in the reduction of the observations, corresponding values of the refraction, reduced to the Pulkowa Tables as a standard. A comparison of these is given below, with the hour angle of the middle point of the arc Δ as argument. This hour angle must be increased $3m$ $18s$ in order to obtain τ.

Refraction. π^6 Orionis, δ Virginis.

t	$-18m$	$-12m$	$-6m$	0	$+6m$	$+12m$	$+18m$
	$''$	$''$	$''$	$''$	$''$	$''$	$''$
Pulkowa, Eq. (47)......	200.77	199.03	198.21	198.25	199.18	201.00	203.78
Bessel, Eq. (60)........	200.78	199.05	198.20	198.24	199.18	201.00	203.73
Diff	−0.01	−0.02	+0.01	+0.01	0.00	0.00	+0.05

The mean of the differences is less than 0″.01, confirming the substantial accuracy of the corrections employed for transforming the refractions computed from the Bessel table with the argument the true zenith distance, to refractions computed from the Pulkowa table, with the argument the apparent zenith distance.

METEOROLOGICAL ELEMENTS AFFECTING THE REFRACTION.

The large influence of the refraction upon the apparent distances of the stars requires that especial care shall be given to the determination of the meteorological elements upon which its computed values depend. To determine the effect upon the refraction of errors in the observed pressure and temperature, we write the expression for R as follows:

$$R = (\alpha)\frac{b}{29.6}\frac{282}{273+t}2\tan\frac{\Delta}{2} \tag{61}$$

where the number 273 represents the assumed temperature of the absolute zero on the Centigrade scale; 282, 29.6, are the normal temperature and pressure of the refraction tables, and b, t represent the observed pressure and temperature. Differentiating the expression, we find

$$dR = R\frac{db}{b} - R\frac{dt}{273+t} \tag{62}$$

and assuming 195′ as an average value of R, it appears that an error of 0.01 inch in the pressure produces an error of 0″.06 in the refraction, and that a temperature in error by 0°.1 C. causes an error of 0″.07.

Determination of Atmospheric Pressure. For the determination of the pressures, the standard barometer of the observatory, Green No. 5162, a cistern barometer with tube 0.7 inches in external diameter, was suspended in the vestibule of the observing room, with its cistern nearly in the plane of the floor of the observing room. In most cases this barometer was read immediately before and after the observation of each pair of stars, but sometimes the pairs were separated by so small an interval of time that an intermediate reading of the barometer was impracticable. The average interval between readings was not far from 30 minutes. Each observed reading of the barometer furnishes a value of the factor β, and all of the values of β derived from a night's work were graphically adjusted, and the value of β corresponding to any desired instant was read from the curve. No corrections for error of the barometer have been applied, since it was not investigated until after the close of this series of observations.

Through the courtesy of the Chief of the Weather Bureau, U. S. Department of Agriculture, a comparison of this barometer with the standard barometer of the Weather Bureau was made by Prof. C. F. Marvin, through the medium of two traveling barometers transported between Washington and Madison. One of these barometers, Adie No. 1601, sustained some injury after the comparison between it and the Madison barometer. The other instrument, Fuess No. 177, was compared at Washington before and after the Madison comparisons. Prof. Marvin has furnished me the following summary of these comparisons.

SUMMARY OF BAROMETER READINGS TO DETERMINE ERROR OF STANDARD BAROMETER, WASHBURN OBSERVATORY:

Date, 1892.		Standard U.S.W.B. Adie No. 1526.	Comparing Barometers. Adie No. 1601. Reading	Adie No. 1601. Cor.	Fuess No. 177. Reading	Fuess No. 177. Cor.	Obs'y Stand'd, Green No. 5162. Reading	Green No. 5162. Cor.	Remarks.
July	18	30.227			30.215	+.012			Comparisons at Washington before transportation to Madison. Mean Corrrection, No. 1601, —.019. Mean Correction, No. 177, +.012.
	19	30.135			30.121	+.014			
Aug.	23	30.189	30.206	—.017					
	24	30 134	30.152	—.018					
	26	29.938	29.956	— 018	29.925	+.013			
	27	30.091	30.112	—.021	30.083	+.008			
	28	30.091	30.111	—.020	30.080	+.011			
Sept.	20		29.197	—0.19	29 172	+.009	29.175	+.005	Comparisons at Madison. Probable Cor. No. 1601, —.019 in. Probable Cor. No. 177, +.009 in. *Readings made with mirror at back of Barometer. †Readings made after cleaning Barometer.
	21		29.102	—0.19	29.078	+.009	29.078	+.007	
	21		29.117	—.019	29.093	+.009	29.094	+.006	
	21		29.085	—.019	29.059	+.009	29.058*	+.009	
	21		29.044	—.019	29.022	+.009	†29.025	+.003	
	22		29.046	—.019	29.023	+.009	†29 024*	+.006	
	22		29.073	—.019	29.051	+.009	†29.055	+.002	
	30	30.336			30.329	+.006			Comparisons after return to Washington. Mean Cor. No. 177, +.007.
Oct.	1	30.168			30.161	+.007			
	5	29.853			29.848	+.005			
	9	29.868			29.859	+.009			
	16	30.044			30.038	+.006			
	17	30.159			30.152	+.007			

On Sept. 21, Green No. 5162 was cleaned, and the last three comparisons between it and the other barometers were made subsequent to the cleaning. In most of the comparisons a piece of white paper was placed behind the barometer and the top of the mercury column was projected against this background in the observations, but for those comparisons which are marked with an * the paper was replaced by a mirror, and the reflection of the instrument from the mirror was observed. This is the method which was employed in connection with the observations of the pairs of stars,

and if there is any systematic difference between it and the other mode of comparison, as seems indicated by the observations, this difference should be included in the correction to the barometer. The mean difference between the readings with mirror and with paper background is 0.002 inches, the mirror giving the smaller reading. This correction I have applied to the comparisons in such a manner as to reduce those made before the cleaning of the barometer to the mirror standard, and those made after cleaning to the paper standard. Designating the Fuess barometer corrected by means of the comparisons made in Washington in July and August as Fuess I, and calling the same barometer corrected by the September and October comparisons Fuess II, we have the following mean results of the comparisons:

CORRECTIONS TO GREEN NO. 5162.

Barometer.	Adie.	Fuess I.	Fuess II.	Adopted.	Background.
	in.	in.	in.	in.	
Before Cleaning.	+0.007	+0.013	+0.008	+0.009	Mirror.
After Cleaning.	.000	+ .009	+ .004	+ .006	Paper.

The average elevation of the telescope objective above the cistern of the barometer I estimate as 330 *cm*, and the correction to the barometer due to this difference of elevation is —0.011 inches; the adopted pressures, which depend upon the state of the barometer before cleaning and used in connection with a mirror, therefore require a correction of — 0.002 inches, a quantity which is considerably smaller than the measure of uncertainty attending its own determination, but which, if regarded as a genuine correction, requires that all the measured distances be diminished by 0".01.

The corrections to the attached thermometer were determined in Washington by Prof. Marvin, who has furnished me the following statement of them:

Temp.	32°	42°	52°	62°	72°	82°	92° F.
Corr.	−0.3	−0.5	−0.4	−0.4	−0.6	−0 6	−0.7

These corrections are included in the comparisons given above, but have not been applied in the computation of the refractions. Their average effect is approximately 0".01, which should be so applied as to increase the measured distances, thus in great part compensating the correction due to index error of the barometer.

Determination of Temperature. For the determination of the temperature of the external air, four thermometers have been employed. They were all made by Green, and are standard meteorological thermometers of such a size that 1° C. is represented on their scales by a space of approximately 2*mm*. The principal points of difference in their construction are shown in the following table:

No.	Bulb.	Divided to
		°
5163	Spherical.	0.5 C.
5164	Spherical.	1.0 F.
6606	Cylindrical.	0.5 C.
6607	Cylindrical.	1.0 F.

The refraction computations are based immediately upon the indications of Nos. 5163, 5164, which were whirled by hand in the open air just south of the observing room. Nos. 6606 and 6607 were employed during the latter part of the work as a control upon the indications of the whirled thermometers. No. 5164 was exclusively employed for the temperatures prior to 1890, Nov. 20, at which date it was broken in whirling at 22*h* 25*m* sidereal time. No. 5163 was immediately substituted for it and was used in all of the subsequent observations. It was found convenient in reading the thermometer to treat it as if each division of its scale corresponded to one degree instead of half a degree, *e. g.*, the temperature 5°.75 C., would be recorded as 11.5 divisions, and the corresponding value of the factor γ interpolated from a table constructed with the argument the temperature expressed in half degrees C.

The indications of a thermometer whirled in the open air are subject to at least two serious sources of error, viz: radiation of heat from the person of the observer, and radiation from the thermometer to the sky. It is apparent that not only do these causes produce effects of opposite sign, but that their relative efficiencies vary in opposite directions as the temperature varies, the former cause having its maximum effect and the latter its minimum at extreme low temperatures. It is therefore *à priori* probable that the temperatures determined with the whirled thermometer are affected with systematic errors varying with the temperature in such a manner that the indications of the thermometer are relatively too high at low temperatures and too low at high temperatures.

To test the existence of such errors a vertical wooden tube of interior cross section 16 × 31 *cm.* was erected just outside the southwest wall of the observing room, and thermometers 6606 and 6607 placed in a sheet iron cage enclosed in the upper part of this tube, with their bulbs opposite apertures in that side of the cage which was turned away from the dome. A cylindrical tube twelve centimeters in diameter connected the bottom of the cage with an exhaust fan driven by clockwork at the rate of 550 revolutions per minute. By the operation of this fan the external air is drawn into the cage through the apertures above described, and flows over the bulbs of the thermometers, which are read by the observer through a permanently closed plate

glass window. Whatever may be the defects of this apparatus, it will be seen that radiation from the observer and radiation to the sky are very nearly if not quite eliminated.

To test the possible effect of the ventilating cage in producing dynamical cooling of the incoming air, on April 16, 1892, I placed in the cage an aneroid barometer, and with a telescope observed its indications when the exhaust fan was running and when it was at rest. During the observations the sky was completely overcast, a light breeze was blowing from the south and the temperature was 51° F. The following summary exhibits the mean results from a series of twenty-two readings of the barometer at an average interval of one minute.

Time.		Fan.	Barometer.	No. of Readings.
21*h*	51*m*	At rest.	28.8833	3
	55	Goin .	.8815	6
22	0	At rest.	.8843	4
	5	Going.	.8813	6
	12	At rest.	.8827	3

These readings indicate a depression of 0.0025 inches, = 0.06*mm*, which is at the very limit of what the barometer is capable of showing, and if the depression is considered as real, it corresponds to a cooling of less than 0°.01 C.

Between July 15 and Dec. 15, 1891, the ventilating apparatus was used in connection with the whirled thermometer on 43 nights, and an inspection of the temperatures furnished by the two methods of exposing the thermometers, indicates systematic differences between them of the character above indicated as probable. Arranging the several comparisons in the order of the temperatures at which they were made, and taking means by groups, there results the data of the following table, in which τ denotes the mean temperature and n the number of comparisons included in each group. The column *V.*—*W.* shows the excess of the temperature indicated by the ventilated thermometers over that given by the whirled thermometers. For the proper appreciation of these differences it should be stated that the ventilating fan was set in motion from five to twelve minutes before the thermometers were read, and that a partial check against sluggishness of the thermometers and insufficient ventilation is afforded by the fact that the bulb of No. 6606 contains about twice as much mercury as the bulb of No. 6607. Any sluggishness would therefore produce a difference in the readings of the thermometers.

In the case of the whirled thermometer, it was my uniform practice to read the thermometer before whirling, then to give the thermometer 60 turns in a circle with a radius of about one meter and read the thermometer, whirl again for 60 turns,

again read, and continue the process until the reading of the thermometer was no longer affected by the whirling. In more than 95 per cent. of all cases the final reading of the whirled thermometer was higher than the initial reading by amounts varying from 0° to 2° C., the average excess being about 0°.3. This result I attribtue to the fact that the thermometer while not actually in use was left in the open air, and its temperature was diminished by radiation to the sky, to a point below that of the surrounding air. It is also possible that radiation from the person of the observer has produced a systematic excess of temperature in the thermometer.

COMPARISON OF THE VENTILATED AND WHIRLED THERMOMETERS.

Limiting Temperatures.	n	τ	$V.-W.$	O.– C.
° °		°	°	°
+28 ...+20 C.	18	+24. C.	+0.14 C.	+0.04
20.... 15	29	17.5	– .08	– .09
15.... 10	37	12.5	– .10	– .03
10... 5	18	7.5	– .06	+ .08
5.... 0	46	+ 2.5	– .19	+ .03
0....– 5	17	– 2.5	– .21	+ .08
– 5....–19	19	–12.5	– .58	– .14

The column O.— C. shows the deviation of the observed values of $V—W$ from the following empirical formula which I have adopted as representing the data

$$V-W = c(\tau - \theta) \tag{63}$$

$$c = +0^\circ.015 \pm 0^\circ.003 \qquad \theta = +17^\circ \pm 3^\circ$$

This difference has been neglected in the reduction of the observations made with the prism apparatus, but is included in the discussion of the results.

Division Errors of the Thermometers. The division errors of the ventilated and whirled thermometers were determined by myself through comparison with a standard thermometer, No. 6799, constructed for me by Green. This is a Centigrade thermometer with cylindrical bulb, and with stem divided to 0°.1 C. The dimensions of the instrument are such that 1° C. = 6.4 *mm.* Through the kindness of the Chief Signal Officer, U. S. A., the corrections to this thermometer were determined in the Signal Office in March, 1891, as follows: "Corrections in degrees Cent. to reduce to standard air thermometer."

Scale.	Cor.	Scale	Cor.
°	°	°	°
−30	0.00	+ 5	+0.05
−25	− .01	+10	+ 05
−20	.00	+15	+ .08
−15	+ .03	+20	+ .05
−10	+ .04	+25	+ .06
− 5	+ .05	+30	+ .08
0	− .04	+35	+ .04
+ 5	+ .05	+40	+ .07

The adopted corrections to the other thermometers determined by a graphical adjustment of the data furnished by the direct comparisons with No. 6799 are as follows:

Scale.	No. 5163.	No. 6606.
°	°	°
−20 C	+0.45 C.	−0.22 C.
15	+ .37	− .15
10	+ .22	− .12
− 5	.00	− .09
0	− .16	− .08
+ 5	− .26	− .06
10	− .34	− .05
15	− .39	− .04
20	− .43	− .03
+25	− .45	− .02

Scale.	No. 5164.	No. 6607.
°	°	°
0 F.	....	−0.20 F.
10	....	− .20
20	....	− .20
30	−0.4 F.	− .20
40	−0.1	− .20
50	−0.0	− .20
60	+0.0	− .20
70	+0.1	− .20
80	.... ..	− .20
90	....	− .20

The thermometer No. 5164 was broken before the standard thermometer was available for comparison, and its corrections have been derived from comparisons made with the thermometer employed for the meteorological service of the observatory, Green No. 515. See Publications W. O., Vol. VII., p. 4. The freezing point of No. 5164 was independently determined Feb. 27, 1890, by Prof. S. J. Brown, who found 32°.3, confirming the otherwise unsatisfactory determination of these corrections.

In the computation of the refraction, R, the corrections to the thermometers were

neglected, and the values of the factor γ were derived from the tables as if the thermometer readings indicated the true temperature of the air. To the refractions thus computed there were applied corrections taken from the following tables constructed from the formula

$$\Delta R = -R\frac{\Delta t}{273+t}$$

in which Δt represents the correction to the thermometer.

5163	ΔR
°	″
−40	−0.38
−30	− .30
−20	− .18
−10	.00
− 0	+ .12
+10	+ .18
+20	+ .23
+30	+ .25
+40	+ .27
+50	+ .28
+60	+ .28

5164	R
°	″
30	+0.12
35	+ .08
40	+ .04
45	.00
50	.00
55	.00
60	.00
65	.00
70	− .04

These corrections are included in the printed values of R.

The substance of the preceding pages may be summed up in the statement that the printed values of the refraction are those which would be furnished by the Pulkowa tables when corrected for the difference in the force of gravity at Pulkowa and Madison, and employed in connection with readings of the meteorological instruments to which all known corrections have been duly applied.

OBSERVING PROGRAMME.

My original observing programme contemplated only a determination of the constant of aberration from observations of the angular distance $\varDelta$ separating a pair of stars. It is shown on p. 33 that the aberration introduces into this distance a variable term of the form

$$2k \cos \beta \sin \frac{\varDelta}{2} \sin (\lambda - s)$$

which has a period of a year, since s denotes the longitude of the sun and λ and β, the coördinates of the middle point of $\varDelta$, are constant. It soon became apparent that an investigation of the absolute amount of the refraction and its seasonal variation might be advantageously combined with the determination of the aberration, and the observing programme was extended so as to include pairs of stars suitable for this purpose. The choice of stars was somewhat narrowly limited by the following considerations: Since the clear aperture available for the formation of an image of each star is less than 50 *mm.*, and a certain amount of light is lost by reflection from the mirrors before reaching the objective, it is apparent that only moderately bright stars can be observed with the apparatus. In the selection of the aberration stars I have therefore included no star whose magnitude is less (fainter) than 6.0 on the scale of the Harvard Photometry. The choice of triplets instead of pairs for the investigation of the refraction, to be hereafter explained, compelled me to somewhat extend this limit, and the faintest star included in the refraction programme is of the 7.2 magnitude. Experience has shown that while the observation of these stars is difficult, with due care its precision may be made but little if at all inferior to that of stars of the second and third magnitudes.

For the aberration, since observations were to be made at an interval of six months, and it was desirable that the conditions under which they were made should be as nearly as possible alike, the longitudes of the stars were determined by the condition that the stars should come into position for observation at epochs in the spring and autumn at which the mean temperatures were, as nearly as practicable, equal. From a discussion of the meteorological records at Madison I find as the expression for the mean daily temperature, T, in degrees F.,

$$T = +45^\circ.2 + 27^\circ.4 \sin (s - 29^\circ.2) \tag{64}$$

Since the observations are necessarily made in the morning and evening twilight, corrections for the diurnal variation of temperature must be applied to this expression in order to obtain the temperature which may be expected at the time of observation on any given date. These corrections are of somewhat uncertain magnitude, but from the best data available I have constructed the following set of values:

	March	April	May	Sept.	Oct.	Nov.
	°	°	°	°	°	°
A. M.	−7.6	−7.6	−7.8	−7.4	−9.1	−7.5
P. M.	+3.6	+4.7	+5.8	+5.4	+4.8	+2.8

from which I find by trial that April 5, P. M., Oct. 8, A. M.; May 1, A. M., and Nov. 3, P. M., are epochs of equal mean temperature. The most favorable position for a pair of aberration stars is therefore defined by the coördinates of the central point of the arc joining the stars, $\lambda = 105°$, or $\lambda = 311°$, differing 90° from the longitude of the sun on the above dates. In all cases it is advantageous to make the latitude of the middle of the arc as small as possible on account of the factor $\cos \beta$ in the expression for the aberration.

The stars observed for a determination of aberration are immediately available for an investigation of the amount of the refraction, since a comparison of the measured distance with its value computed from the known coördinates of the stars will furnish a numerical value for the amount of the refraction, $\alpha \beta^{A} \gamma^{\lambda} 2 \tan \frac{\Delta}{2}$, from which the value of α, or a correction to α, may be derived. This value is, however, open to the criticism of depending upon the assumed places of the stars, and I have thought it desirable to avoid this objection in the following manner: If a and b represent two stars near the equator and approximately 120° apart, and c be a third star situated at that point of the celestial sphere diametrically opposite to the middle point of the arc ab, then will c be 120° distant from both a and b, and its distance from each of these may be measured with the prism apparatus. Such a set of three stars I designate a triplet, and if each of the three arcs, ab, bc, ca, be measured and the measured length be projected upon the equator by means of the declinations of the stars, it is evident that the sum of the projections must equal 360°, and the refraction must be so determined as to satisfy this condition. The resulting value of the refraction will not depend in any way upon the right ascensions of the stars, and will involve only the squares and products of their declinations, and these terms may be rendered very small by selecting the stars near the equator. It is evident that the refraction triplets are subject to no limitations of longitude in their selection, or of time in the dates of observation. In arranging the observing program for each evening, those aberration pairs which were suitably placed for observation were always given precedence, and observations of the refraction pairs were confined to dates at which they would not conflict with the aberration work.

The selections from the star catalogues of pairs of stars which satisfy the conditions above determined is a very laborious process, and it may well be that a more advantageous selection of pairs than is contained in my observing list could have been made. The selection of the triplets is even more laborious than that of the aberration pairs, and my thanks are due to M. Loewy, of the Paris Observatory, who kindly undertook to select for me from his large stellar globe every set of triplets contained in the heavens which satisfy the following conditions: Each star to be of the sixth magnitude or brighter. Each star to be within five degrees of the equa-

tor. Each star to be separated from each of the others composing the triplet by an arc whose length was included between the limits 119° 53′ and 120° 13′. M. Loewy communicated to me three triplets satisfying these conditions. Two of these I had previously found from the catalogues.

The observing lists for both aberration and refraction stars which are contained in the following pages comprise, in addition to the names and magnitudes of the stars, a symbol employed as a brief representation of the pair, and certain quantities required for pointing the telescope so as readily to find and identify the stars. T is the sidereal time at which the stars comprising a pair have equal altitudes, and are therefore most favorably situated for observation, The right ascension and declination of the middle point of the arc, $\varDelta$, joining the stars are given under the headings α_0, δ_0, and by means of its circles the telescope is directed toward this point of the heavens. P represents the angle between the arc $\varDelta$ and the hour circle passing through the middle point of $\varDelta$, reckoned positive from the hour circle toward the star having the greater right ascenston. In pointing the telescope it was rotated in its cradle until the reading of the P circle corrected for index error equalled P, in which position the axis of the reel is approximately perpendicular to the plane of the arc $\varDelta$. The column of Epochs indicates the dates at which the aberration produces its maximum positive and negative effects upon $\varDelta$. The column $\varDelta'$ denotes the excess of $\varDelta$ over 120°.

After the quantities α_0, δ_0 and P had been set off upon their respective circles the reel was rotated about its axis by means of the endless cord so as to bring the images of the stars into the field of view. The apparent distance between the images should be $\varDelta'$ diminished by the refraction, approximating 200″, and this criterion, together with the magnitude of the stars, served as a safeguard against the observation of a wrong pair.

It is shown in previous pages that the effect of aberration and refraction upon the measured distances is represented by means of equations involving the following quantities, which are approximately constant for each pair of stars:

$\varDelta_0$. The true distance between a pair of stars.

$T_0 + \vartheta$. The sidereal time at which the effect of refrac ion is a minimum.

(α'). Bessel's refraction coefficent, corrected for the effect of second order terms.

λ'. The exponent of the temperature factor, γ.

h_0'. The coefficient of the differential refraction expressed in parts of a revolution of the micrometer screw.

f. The aberration coefficient.

λ. The longitude of the middle point of the arc $\varDelta_0$.

L. The zenith distance of the middle point of $\varDelta_0$ at the instant $T_0 + \vartheta$.

μ. The annual effect of proper motion upon $\varDelta_0$

The values of these constants computed from the coördinates of the stars referred to the equinox of 1890.0, are given in the following Table of Reduction Constants. The distances, $\varDelta_0$, are given for the epoch 1890.0. The assumed coördinates and proper motions of the stars from which these distances were computed are treated in a subsequent section.

The formulæ from which these several quantities were computed are as follows: The subscripts 1 and 2 refer respectively to the star having the lesser and the greater right ascension.

$$\begin{aligned}
\cos \Delta &= \sin \delta_1 \sin \delta_2 + \cos \delta_1 \cos \delta_2 \cos (\alpha_2 - \alpha_1) \\
\tfrac{1}{2}(\alpha_2 + \alpha_1) &= a \qquad\qquad \tfrac{1}{2}(\delta_2 + \delta_1) = c \\
\tfrac{1}{2}(\alpha_2 - \alpha_1) &= b \qquad\qquad \tfrac{1}{2}(\delta_2 - \delta_1) = d \\
\tan x &= \tan b \tan c \tan d \\
\alpha_0 &= a - x \\
\sin \delta_0 &= \sin c \cos d \sec \frac{\Delta}{2} \\
\cos P &= \cos c \sin d \operatorname{cosec} \frac{\Delta}{2} \sec \delta_0 \\
\tan m &= \sin \delta_0 \cot P \\
\sin (\tau + m) &= \tan \varphi \cot \delta_0 \sin M \\
T &= \alpha_0 - \tau \\
\cos z_1 &= \sin \varphi \sin \delta_1 + \cos \varphi \cos \delta_1 \cos (T - \alpha_1) \\
\cos z_2 &= \sin \varphi \sin \delta_2 + \cos \varphi \cos \delta_2 \cos (T - \alpha_2)
\end{aligned} \tag{65}$$

Since T is the instant at which the stars have equal altitudes, the last equations should furnish $z_1 = z_2$, and this agreement furnishes a check upon the accuracy of the computation.

The α_0, δ_0 above derived were transformed into longitude and latitude, λ, β, by the formulæ,

$$\begin{aligned}
\tan N &= \sin \alpha_0 \cot \delta_0 \\
\tan \lambda &= \tan \alpha_0 \operatorname{cosec} N \sin (N + \varepsilon) \\
\sin \beta &= \sin \delta_0 \sec N \cos (N + \varepsilon)
\end{aligned} \tag{66}$$

and the computation verified by the relation

$$\sin \lambda \cot \beta = \tan (N + \varepsilon) \tag{67}$$

The zenith distances z_1 and z_2 above derived furnished the arguments with which α' and λ' were derived from the refraction tables. The interpolation of these quantities and the computation of ϑ, f and h_0' were made in duplicate. The formulæ for all of the reduction constants have been derived in the preceding pages

OBSERVING LIST OF ABERRATION PAIRS.

Stars.	Pair.	Mag.	T α_0		P. δ_0		Epochs.	Δ'	Remarks.
			h.	m.	°	′		′	
α Piscium.	I.	4.0	5	38.8	83	55	March 19	+ 7	Dup.
α Leonis.		1.4	5	54.7	+ 14	50	Sept. 21		
γ Ceti.	II.	3.3	6	23.7	85	4	March 29	+ 9	
l Leonis.		5.1	6	36.9	+ 14	0	Oct. 2		
32 Eridani.	III.	5.0	7	9.2	78	29	April 15	− 1	* 6.7 near.
95 Leonis.		5.6	7	41.6	+ 12	52	Oct. 18		
μ Tauri.	IV.	4.5	8	21.4	92	41	April 23	+10	
c Virginis.		5.2	8	13 9	+ 12	30	Oct. 26		
π^4 Orionis.	V.	4.0	8	45 7	89	0	May 3	+ 6	* 6.5 near.
δ Virginis.		3.0	8	49.0	+ 6	16	Nov. 5		
ϑ Can. Maj	VI.	4.3	9	19 3	66	28	May 24	− 1	
ε Bootis.		2 6	10	26.0	+ 14	50	Nov. 24		
ε Tauri.	VII.	3.6	9	52.2	113	51	April 25	0	
ε Corvi.		3.1	8	9 7	− 2	53	Oct. 28		
119 Tauri.	VIII.	4.7	10	25 8	106	58	May 13	+ 7	
α Virginis.		1.2	9	29.5	+ 7	42	Nov. 14		
γ Geminorum.	IX.	2.3	11	3.8	98	31	May 26	+ 3	
109 Virginis.		3 6	10	44 6	+ 18	59	Nov. 27		
μ Virginis.	X.	3.9	18	3.7	81	3	Oct. 2	+ 5	
ζ Pegasi.		3.3	18	34.2	+ 5	3	March 30		
φ Virginis.	XI.	5.0	18	20.3	89	20	Sept. 29	+ 7	
ζ Aquarii.		3.8	18	22.9	− 2	19	March 26		
37 Librae.	XII.	5.0	18	38.1	77	21	Oct. 16	+ 2	
0 Pegasi.		5.0	19	24.3	+ 2	25	April 12		

OBSERVING LIST OF ABERRATION PAIRS—Continued.

Stars.	Pair.	Mag.	T α_0		P δ_0		Epochs.	′	Remarks.
			h.	m.	°	′		′	
β Librae.	XIII.	2.0	18	45 2	83	14	Oct. 12	+ 8	
γ Piscium.		4.0	19	13.5	− 6	17	April 8		
3 Serpentis.	XIV.	5.3	19	35.4	96	55	Oct. 11	+ 6	
φ Aquarii.		4.3	19	8.7	− 1	17	April 8		
δ Ophiuchi.	XV.	3 0	20	24.9	93	33	Oct. 24	+ 8	
ι Ceti.		3.3	20	8.8	− 12	56	April 21		
ε Serpentis.	XVI.	3.3	20	43.0	104	26	Oct. 16	− 5	
108 Aquarii.		5.0	19	34.4	− 14	29	April 12		
B. A. C. 5903.	XVII.	5 3	21	13.0	87	1	Nov. 17	+ 6	* 6.0 near.
μ Piscium.		5.1	21	22.9	+ 6	0	May 16		
B. A. C. 5647.	XVIII	5.8	21	36.0	104	17	Nov. 5	+ 4	* 5.7 near.
17 Ceti.		5.0	20	43.2	+ 2	12	May 3		
ι Coronae.	XIX.	4.2	21	40.0	118	44	Oct. 28	+ 9	
A^2 Aquarii.		4.6	20	8.1	+ 10	46	April 26		
5 H Scuti.	XX.	5.0	22	12 7	83	32	Dec. 1	+ 6	
γ Ceti.		3.3	22	39.5	− 5	36	May 30		
ν Aquilae.	XXI.	4.8	22	57.5	82	41	Dec. 17	+ 8	
f Tauri.		4.0	23	17.9	+ 12	42	June 16		

OBSERVING LIST OF REFRACTION TRIPLETS.

Stars.	Pair.	Mag.	T	α_0	P	δ_0	Δ'	Remarks.
			h.	m.	°	'		
16 Aquarii.	A (1)	5 9	1	5.7	87	22	+ 2	
o Orionis.		4.7	1	16.5	− 5	31		
β Piscium.	B (1)	4.6	3	13.9	94	13	− 5	
19 Monocerotis.		4.8	2	57.7	− 0	51		
f Piscium.	C (1)	5.0	5	31.4	95	10	− 5	
23 Hydrae.		5.5	5	10.9	− 2	51		
B. D. − 0°,258.	D (1)	7.2	5	34.1	89	55	− 5	
ι Hydrae.		4.1	5	34.4	− 1	27		
α Ceti.	E (1)	2.7	7	18.4	93	12	− 1	
p² Leonis.		5.0	6	56.7	+ 1	46		
10 Tauri.	F (1)	4.5	7	31.9	90	9	+ 1	
υ Leonis.		4.5	7	31.3	− 0	10		
o Orionis.	A (2)	4.7	9	9.4	88	11	− 1	
B. D. + 2°,2664.		5.6	9	16.0	+ 2	10		
19 Monocerotis.	B (2)	4.8	10	43.0	86	11	+ 4	
110 Virginis.		4.6	10	57.8	− 1	33		
23 Hydrae.	C (2)	5.5	12	55.1	85	49	− 6	
U Ophiuchi.		5.9	13	12.1	− 4	33		*var.*
ι Hydrae.	D (2)	4.1	13	34.2	89	58	+ 0	
Ll 32290.		6.5	13	34.3	− 1	18		
p² Leonis.	E (2)	5.0	15	1.1	91	8	− 1	
g Aquilae.		5.5	14	56 3	− 5	45		
υ Leonis.	F (2)	4.5	15	34.1	90	46	− 5	
τ Aquilae.		4.4	15	31.1	− 1	45		

OBSERVING LIST OF REFRACTION TRIPLETS—Continued.

Stars.	Pair.	Mag.	T α_0		P δ_0		Δ'	Remarks.
			h.	*m.*	°	′		
B. D. + 2°,2664.	A (3)	5.6	17	32.6	94	27	− 6	
16 Aquarii.		5.9	17	15.2	− 2	21		
110 Virginis.	B (3)	4.6	18	56.4	89	36	− 1	
β Piscium.		4.6	18	57.7	+ 5	45		
U Ophiuchi.	C (3)	5.9	21	8.0	89	1	+ 9	
f Piscium.		5.0	21	11.4	+ 4	23		Another pair near.
Ll 32200.	D (3)	6.5	21	34.9	90	8	+ 4	
B. D. − 0°,258.		7.2	21	34.4	− 1	23		
g Aquilae.	E (3)	5.5	22	40.5	85	40	− 0	
α Ceti.		2.7	22	56.9	− 0	12		
ι Aquilae.	F (3)	4.4	23	27.7	89	5	+ 3	
10 Tauri.		4.5	23	31.2	− 1	29		

TABLE OF REDUCTION CONSTANTS.

Stars.	$T+\vartheta$			$\Delta_0 - 119°$		μ	*Log f*	λ		*Log* α'	λ'	*Log* h'_0	L
	h.	m.	s.	'	"	"		°	'				°
A (1)	1	5	42	61	52.90	+ 0.034	1.5387	15	31	1.75663	1.010	6.5062	48
B (1)	3	13	52	55	21.88	− .015	.5296	41	48	.75742	.008	.4333	44
C (1)	5	31	25	55	1.45	+ .097	.5039	76	28	.75711	.009	.4605	46
D (1)	5	34	5	55	17.77	+ .046	.5073	82	57	.75736	.008	.4434	45
I	5	38	50	67	23.78	− .288	.5446	88	43	.75884	.005	.2670	28
II	6	23	44	69	5.15	+ 0.187	1.5439	99	5	1.75879	1.005	6.2762	29
III	7	9	9	59	2.98	− .084	.5445	115	1	.75871	.005	.2615	31
E (1)	7	18	22	58	34.19	+ .045	.5199	105	12	.75776	.007	.4014	41
F (1)	7	31	55	60	52.08	+ .209	.5178	114	41	.75753	.008	.4281	43
IV	8	21	43	68	45.16	− .270	.5463	122	53	.75872	.005	.2906	30
V	8	45	43	65	43.51	− 0.490	1.5412	132	56	1.75824	1.006	6.3523	37
A (2)	9	9	24	58	40.56	− .093	.5378	140	43	.75783	.007	.3965	41
VI	9	19	9	58	43.97	+ .083	.5478	152	49	.75865	.005	.1569	31
VII	9	52	45	60	21.85	− .187	.5150	125	25	.75601	.011	.3951	52
VIII	10	25	59	67	7.14	− .063	.5465	142	14	.75818	.006	.2864	38
B (2)	10	43	0	63	50.98	− 0.060	1.5456	166	17	1.75730	1.008	6.4468	45
IX	11	8	57	62	51.45	− .146	.5424	155	25	.75905	.004	.2286	25
C (2)	12	55	6	54	12.14	− .023	.5485	198	22	.75681	.009	.4865	48
D (2)	13	34	10	60	15.57	− .072	.5451	202	17	.75788	.008	.4423	44
E (2)	15	1	5	59	1.73	+ .018	.5418	223	22	.75658	.010	.5092	49
F (2)	15	34	5	54	35.69	− 0.007	1.5302	230	51	1.75731	1.008	6.4472	45
A (3)	17	32	39	54	30.46	+ .030	.5203	258	2	.75719	.007	.4539	46
X	18	3	40	65	10.22	− .029	.4945	279	42	.75807	.006	.3527	39
XI	18	20	23	67	15.69	+ .355	.5196	276	9	.75719	.008	.4596	46
XII	18	37	58	61	58.58	− .206	.5126	293	2	.75769	.007	.3710	42

TABLE OF REDUCTION CONSTANTS—Continued.

Stars.	$T+\vartheta$			$\Delta_0 - 119°$		μ	*Log f*	λ		*Log* α'	λ'	*Log* h'_0	L
	h.	*m.*	*s.*	′	″	″		°	′				°
XIII	18	45	12	68	4.42	+ 0.619	1.5324	289	2	1.75637	1.010	6.5161	50
B (3)	18	56	23	59	5.17	+ .070	.4935	286	23	.75821	.006	.3551	38
XIV	19	35	33	64	36.73	+ .056	.5194	288	28	.75731	.008	.4385	45
XV	20	25	0	67	53.98	− .018	.5462	301	34	.75456	.014	.6415	56
XVI	20	43	20	55	21.40	− .101	.5457	293	0	.75312	.016	.6645	60
C (3)	21	7	59	69	23.62	− 0.069	1.5235	321	43	1.75805	1.006	6.3744	39
XVII	21	18	1	65	41.21	+ .385	.5216	325	10	.75821	.006	.3538	37
D (3)	21	34	56	61	58.49	+ .028	.5392	325	28	.75731	.008	.4156	44
XIX	21	40	25	69	4.91	+ .042	.4849	305	42	.75307	.006	.1377	39
XX	22	12	48	65	31.63	− .183	.5489	339	19	.75653	.010	.5044	49
E (3)	22	40	32	59	44.45	− 0.067	1.5468	345	24	1.75751	1.008	6.4260	44
XXI	22	57	37	67	37.70	+ .026	.5327	355	30	.75872	.005	.2810	31
F (3)	23	27	44	62	48.14	− .217	.5492	352	50	.75733	.008	.4465	45

The method by which the refractions computed from the constants contained in the preceding table have been transformed to the system of the Pulkowa Refraction Tables has been already explained. The reductions actually employed have been interpolated from the following table, in which the columns α and λ have the same significance as α', λ' of the preceding table, save that the argument upon which they depend is the apparent zenith distance of the stars at the instant $T+\vartheta$, and further that the correction for difference in the force of gravity at Pulkowa and Madison, — 64 units of the fifth decimal place, has been applied to *log* α. *

* The theory of this correction, which is neglected in all the text books, is as follows: Assuming equal density of the atmosphere at any two places whose latitudes are φ and φ', the corresponding heights of the barometric column will be inversely proportional to the force of gravity, *i. e.*,

$$p : p' :: g' : g :: 1 - a \cos 2\varphi' : 1 - a \cos 2\varphi$$

from which

$$\log p = \log p' + 2\, a\, M \sin(\varphi' - \varphi) \sin(\varphi' + \varphi)$$

where $M = 0.4343$ and $a = 0.0026$. Since the barometric factor B of the refraction tables contains p as a factor, we may write in units of the fifth decimal place

$$\log B = \log B' + 225 \sin(\varphi' - \varphi) \sin(\varphi' + \varphi)$$

Tables which for any given latitude φ, give a correct value of $\log B$, when employed for any other latitude will furnish a value $\log B'$, which must be corrected by the last term of the preceding equation. For most purposes this term may be united with the factor α of the tables under the form

$$\Delta \log \alpha = +225 \sin(\varphi' - \varphi) \sin(\varphi' + \varphi)$$

The column $P - B$ furnishes the reduction from the computed refractions to the Pulkowa standard at the temperatures 0° and 100° F., but it must not be considered a comparison of the Bessel and Pulkowa tables.

REDUCTION OF THE REFRACTIONS TO THE PULKOWA STANDARD.

Pairs.	App't Z. D.	Log α	λ	P. − B.	
				0° F.	100° F.
	° ′			″	″
A (1)	70 40.8	1.75533	1.0111	− 0.59	− 0.92
B (1)	68 52.9	.75612	.0092	.60	.92
C (1)	69 40.0	.75580	.0100	.59	.92
D (1)	69 2.8	.75605	.0094	.60	.92
I	63 56.5	.75750	.0059	.63	.94
II	64 9.5	1.75746	1.0060	− 0.63	− 0.94
III	64 35.2	.75737	.0062	.62	.94
E (1)	67 55.5	.75646	.0085	.60	.93
F (1)	68 36.3	.75622	.0090	.60	.92
IV	64 33.0	.75738	.0061	.63	.94
V	66 24.2	1.75693	1.0073	− 0.61	− 0.93
A (2)	67 45.6	.75652	.0083	.60	.93
VI	64 46.1	.75733	.0063	.62	.94
VII	71 47.6	.75478	.0127	.58	.92
VIII	66 37.7	.75687	.0075	.61	.93
B (2)	69 10.9	1.75600	1.0095	− 0.60	− 0.92
IX	62 54.7	.75770	.0055	.64	.94
C (2)	70 17.6	.75552	.0106	.59	.92
D (2)	68 59.5	.75607	.0093	.60	.92
E (2)	70 44.8	.75531	.0112	.58	.92
F (2)	69 9.5	1.75600	1.0095	− 0.60	− 0.92
A (3)	69 27.0	.75589	.0097	.59	.92
X	67 0.2	.75676	.0077	.61	.93
XI	69 26.8	.75589	.0097	.59	.92
XII	68 8.3	.75640	.0085	.60	.93

REDUCTION OF THE REFRACTIONS TO THE PULKOWA STANDARD—Continued.

Pairs.	App't Z. D.	Log α	λ	P. — B.	
				0° F.	100° F.
	° ′			″	″
XIII	71 9.4	1.75768	1.0118	− 0.58	− 0.92
B (3)	66 31.7	.75689	.0074	.61	.93
XIV	69 11.5	.75599	.0095	.60	.92
XV	73 48.1	.75336	.0162	.57	.91
XVI	75 17.7	.75193	.0192	.56	.91
C (3)	67 3.2	1.75675	1.0077	− 0.61	− 0.93
XVII	66 30.5	.75690	.0074	.61	.93
D (3)	69 3.6	.75605	.0094	.60	.92
XIX	67 0.2	.75676	.0077	.61	.93
XX	70 51.3	.75525	.0113	.58	.92
E (3)	68 40.1	1.75619	1.0090	− 0.60	− 0.92
XXI	64 33.2	.75738	.0062	.62	.94
F (3)	69 6.3	.75603	.0094	.60	.92

To elucidate the use of the several quantities discussed and tabulated in the preceding pages, I give in full the record and reduction of an observation of a pair of stars. Matter printed in italics in the record is not contained in the original notes of the observation, but has been added as the equivalent of that which the observer denoted by the part of the page upon which the recorded figures were written. The readings of the ventilated thermometer were always made in the interval between the observations Cord Down and Cord Up.

Quantities which in the following Reduction of Observations are marked with an * were transferred by myself to the reduction blanks and the copying checked. The computations from these data were made by Mr. John A. Parkhurst, at Marengo, Illinois, distant some seventy-five miles from the observatory. Since the computations were thus to be made without my personal supervision, and it did not seem feasible to have them made in duplicate, I have abstained from introducing into the forms of computation any of those abbreviations which, however advantageous they may be for the experienced computer, are a prolific source of error to those not accustomed to their use. The agreement which the individual results should show, one with another, when the correction for differential refraction ΔM is applied, furnishes

a partial check upon the computing, while the care bestowed upon the computations by Mr. Parkhurst is shown by the fact that in the numerous revisions to which I have had occasion to subject parts of his work I have not found a single error of consequence.

The correction Δ *Ref*^{n}, which is given in connection with the computed refraction, is that above derived for passing from the Bessel constants to those of the Pulkowa tables corrected for gravity. The correction Δ *Mic.*, which is to be applied to *d*, is due in part to the progressive inequality of the screw and in part to the reduction of the observations with a provisionally adopted value of a revolution of the micrometer screw 0".023 greater than the finally adopted value. Both of these corrections were introduced by myself in passing from the reduction sheets to the tabulated results for the several pairs.

RECORD AND REDUCTION OF OBSERVATIONS.

1891, THURSDAY, DECEMBER 17. OBSERVER, G. C. C.

β Piscium 19 Monocerotis

Ocular V

Bar. 29.391	*Att. T.* 18°.5	*Vent. T* + 16°.7 *F.*		*Bar.* 29.392		*Att. T.* 18°.5	
Sid. Time 2 h. 58 m.	*Ext T.* − 16.0	− 17.5		*Sid. Time* 3 h. 28 m.		*Ext. T.* − 16.0	

Angles	I		II		III	
	h. m. s.	r.	m. s.	r.	m. s.	r.
	2 59 55	65.68	4 1	65.81	7 11	64.50
Cord Down	3 0 42	.69	4 45	.77	8 18	.51
	2 31	.63	5 27	.76	8 57	.54
			P Circle = 250° 8′			
	22 55	31.07	19 15	30.88	16 25	32.10
Cord Up	23 45	.02	20 26	.89	17 18	.08
	25 12	.08	21 26	.85	18 0	.11

Superb night. Everything favorable.

Angle. *	T *	τ	*log M*	*log Δ M*	Δ *M*	*M* *	*M′*
	h. m. s.	m s.			r.	r.	r.
I	2 59 55	− 14 16	2.602	9.060	− 0.115	65.68	65.565
	3 0 42	13 29	2.558	9.011	.103	.69	.587
	2 31	11 40	2.427	8.885	.077	.63	.553

RECORD AND REDUCTION OF OBSERVATIONS—Continued.

Angle. *	T *	τ	log M	log Δ M	Δ M	M *	M'
	h. m. s.	m. s.			r.	r.	r.
II	4 1	− 10 10	2.307	8.765	− .058	65.81	65.752
	4 45	9 26	2.242	8.700	.050	.77	.720
	5 27	8 44	2.175	8.633	.043	.76	.717
III	7 11	7 0	1.983	8.441	.028	64.50	64.472
	8 13	5 58	1.844	8.302	.020	.51	.490
	8 57	− 5 14	1.731	8.189	.015	.54	.525
III	16 25	− 2 14	0.991	7.449	+ .003	32.10	32.103
	17 18	3 7	1.280	7.738	.005	.08	.085
	18 0	3 49	1.456	7.914	.008	.11	.118
II	19 15	5 4	1.702	8.160	.014	30.88	30.894
	20 26	6 15	1.885	8.343	.022	.89	.912
	21 26	7 15	2.014	8.472	.030	.85	.880
I	22 55	8 44	2.175	8.633	.043	31.07	31.113
	23 45	9 34	2.254	8.712	.052	.02	.072
	25 12	+ 11 1	2.377	8.835	+ .068	.03	.098

	r.	r.		s.		
M' I	65.568	31.094	* Δ T	− 19	* β	− 0.00249
M' II	65.730	30.895	log h'	6.458	* γ	+ 0.02733
M' III	64.496	32.102	λ	41 43	$\overset{\lambda'}{\beta\gamma}$	+ 0.02506
* Coincidence	48.300		* s	265 57	α'	1.75742
d I	7' 53".84	7' 52".13	sin (λ − s)	9.8436	$\overset{\lambda'}{\alpha\beta\gamma}$	1.78248
d II	7 58 .28	7 57 .60	f	1.5296	$2\ tg\ \frac{\Delta}{2}$	0.53897
d III	7 24 .42	7 24 .48	Aberrat'n	+ 23".62	Ref'n	3' 29".63
Mean	7' 45".51	7' 44".74			Δ Ref.n	− 0.78
d = − 7' 45".13						
Δ Mic. + 0.38						

It is not feasible for me to print all of the details of the observations of each pair of stars, but the following Tabulated Results of Observations contain for each observation made with the reel between September 21, 1890, and July 11, 1892, the date, observer and adopted temperature, the latter derived from a graphical adjustment of all the thermometer readings of a given night. There are also given upon each lef hand page the adopted value of the instrumental correction K; the distance d derived from the mean of all the micrometer pointings after correction for differential refraction; the value of the refraction, R, at the instant $T + \vartheta$; and the computed effect of aberration, A, upon the distance between the stars. The resulting value of the distance

$$\Delta = 120^\circ + K + d + R + A$$

is given in the eighth column. The column μ gives the reduction to 1890.0 for the effect of proper motion. The columns τ, $\varphi(d)$, n, f, A, and B, relate to the discussion of the observations and are hereafter explained. The column p denotes the weight assigned to the observation and v is the residual furnished by the observation in the final solution. The quantity D given upon each left hand page is the assumed mean value of Δ.

A (1) 16 AQUARII. *o* ORIONIS.

Date.		Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
			div.	"	′ "	′ "	′ "	"
1890. October	20	C.	+ 9.4	+ 0.35	− 1 18.92	+ 3 17.45	− 0 7.35	51.53
	21	F.	+ 8.3	+ .35	17.17	17.90	7.96	53.12
	26	C.	+ 5.6	+ .35	17.69	19.12	10.81	50.97
November	4	C.	+ 2.7	+ .35	9.90	17.24	15.80	51.89
	5	F.	+ 12.0	+ .21	6.66	14.45	16.34	51.66
	10	C.	− 5.7	+ .35	13.06	24.02	18.95	52.36
	11	F.	+ 4.5	+ .35	8.43	19.69	19.44	52.17
	12	C.	+ 0.8	+ .35	9.41	21.00	19.95	51.99
	13	F.	+ 11.0	+ .35	4.96	15.43	20.43	50.39
	18	C.	+ 10.5	+ .35	1.81	16.20	22.80	51.94
	19	F.	+ 9.2	+ .35	3.86	17.96	23.26	51.19
	20	C.	+ 8.2	+ .35	2.46	16.99	23.71	51.17
	21	F.	+ 10.2	+ .35	1.61	18.12	24.14	52.72
	23	F.	+ 1.3	+ .35	2.89	19.72	25.00	52.18
	25	F.	− 3.6	+ .35	4.67	23.21	25.82	53.07
	27	F.	− 5.2	+ .21	1 3.08	23.29	26.62	53.80
December	9	F.	− 3.4	+ .35	0 56.04	18.34	30.66	51.9[illegible]
1891. December	10	C.	+ 10.0	− .03	54.63	17.93	30.87	52.40
	11	C.	+ 3.4	− .03	59.30	22.66	31.14	52.19
	12	C.	+ 3.5	− .03	− 0 56.72	+ 3 20.71	− 0 31.41	52.55

$D = 120° 1' 52''.00$

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
− 0.03	− 0.17	+ 0.03	+ 0.64	+ 0.37	+ 1.85	− 0.60	1.	+ 0.46	1890. Oct. 20
.03	− .16	....	....	....	....	....	0.	....	21
.03	− .07	+ .03	+ 1.10	0.53	1.79	0.79	1.	+ .92	26
.03	− .05	+ .02	+ 0.17	0.77	1.68	1.07	1.	.00	Nov. 4
.03	− .09	....	+ 0.46	0.80	1.67	1.10	0.5	+ .29	5
.03	+ .02	+ .02	− 0.37	0.93	1.58	1.24	1.	− .54	10
.03	− .03	....	− 0.11	0.95	1.55	1.27	0.5	− .27	11
.03	− .06	+ .02	+ 0.02	0.98	1.54	1.30	1.	− .14	12
.03	− .10	....	....	....	....	....	0.	....	13
.03	− .09	+ .02	+ 0.16	1.11	1.40	1.45	1.	+ .01	18
.03	− .08	....	+ 0.92	1.13	1.38	1.47	0.5	+ .77	19
.03	− .17	+ .02	+ 1.01	1.15	1.35	1.50	1.	+ .86	20
.03	− .04	....	− 0.65	1.18	1.32	1.52	0.5	− .80	21
.03	+ .01	....	− 0.16	1.22	1.28	1.56	0.5	− .81	23
.03	+ .02	....	....	....	....	....	0.	....	25
.03	+ .02	....	....	....	....	....	0.	....	27
.03	+ .01	....	+ 0.03	1.50	0.83	1.88	0.5	− .09	Dec. 9
.07	− .08	+ .02	− 0.27	1.51	0.80	1.89	1.	− .39	1891. Dec. 10
.07	− .06	+ .02	− 0.08	1.53	0.77	1.90	1.	− .20	11
− 0.07	− .05	+ .02	− 0.45	+ 1.54	+ 0.74	− 1.91	1.	− .56	12

B (1). *β* Piscium. 19 Monocerotis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Dec. 8	F.	− 22.1	+ 0.35	− 7 52.56	+ 3 27.85	− 0 17.09	18.55
9	F.	− 0.6	+ .35	− 7 37.40	17.08	− 0 20.08	19.95
1891. Sept. 9	C.	+ 23.0	− .02	− 8 20.93	13.62	+ 0 27.50	20.17
10	C.	+ 23.8	− .02	20.11	12.54	27.16	19.57
13	C.	+ 19.5	− .02	19.99	13.67	26.10	19.76
20	C.	+ 38.6	− .02	10.69	7.30	23.36	19.95
21	C.	+ 40.0	− .02	10.35	7.10	22.95	19.68
22	C.	+ 36.9	− .02	− 8 9.43	7.60	+ 0 22.51	19.66
Dec. 11	C.	+ 3.3	− .02	− 7 40.93	22.51	− 0 20.91	20.65
17	C.	− 16 0	− .02	44.72	28.85	23.62	20.49
23	C.	− 5.5	− .02	− 7 36.20	+ 3 21.36	− 0 26.06	19.08

C (1). *f* Piscium. 23 Hydrae.

		div.	″	′ ″	′ ″	′ ″	″
1891. Sep. 28	C.	+ 15.0	− 0.03	− 8 45.01	+ 3 14.93	+ 0 30.06	59.95
29	C.	+ 13.1	− .03	45.77	16.68	29.87	60.75
Oct. 8	C.	+ 11.4	− .03	44.64	16.74	27.78	60.05
9	C.	+ 9.5	− .03	44.19	17.12	27.51	60.39
11	C.	+ 10.7	− .03	45.32	18.38	26.94	59.97
15	C.	− 3.0	− .03	47.93	21.94	25.69	59.67
19	C.	+ 4.8	− .03	42.94	18.44	24.33	59.80
21	C.	+ 2.3	− .03	45.23	20.98	+ 0 23.59	59.31
1892. Mch. 1	C.	− 11.3	− .03	− 7 56.19	26.06	− 0 31.81	58.08
2	C.	− 0.3	− .03	− 7 50.88	+ 3 21.12	− 0 31.43	58.78

D = 119° 55′ 21″.00

μ	τ	$\varphi (d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+ 0.01	+ 0.39	....	....	....	....	....	0.	....	1890. Dec. 3
.01	+ .15	....	+ 0.89	+ 0.98	+ 0.82	− 1.87	0.5	+ 0.66	9
.03	− .41	+ 1.20	+ .01	− 1.35	1.71	+ 0.75	1.	− .27	1891. Sept. 9
.03	− .35	1.20	+ .55	1.33	1.73	0.72	1.	+ .27	10
.03	− .24	1.20	+ .25	1.28	1.76	0.62	1.	− .03	18
.03	− .71	1.16	+ .57	1.14	1.83	0.40	1.	+ .29	20
.03	− .81	1.16	+ .94	1.12	1.84	0.37	1.	+ .66	21
.03	− .63	1.16	+ .78	− 1.10	1.85	+ 0.33	1.	+ .50	22
.03	+ .05	1.02	− .75	+ 1.02	0.76	− 1.87	1.	− .96	Dec. 11
.03	+ .35	1.04	− .91	1.15	0.56	1.97	1.	− 1.20	17
+ .03	+ .09	+ 1.00	+ .80	+ 1.27	+ 0.85	− 2.02	0.5	+ .61	23

D = 119° 54′ 60″.50

μ	τ	$\varphi (d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
− 0.16	− 0.15	+ 1.33	− 0.47	− 1.47	+ 1.89	+ 0.13	1.	+ 0.21	1891. Sept. 28
− .16	− .13	1.33	− 1.29	1.46	1.90	+ 0.09	1.	− 1.03	29
− .16	− .10	1.33	− 0.62	1.36	1.92	− 0.21	1.	− .36	Oct. 8
− .16	− .04	1.32	− 1.01	1.35	1.92	0.24	1.	− .75	9
− .16	− .08	1.33	− 0.56	1.32	1.91	0.31	1.	− .30	11
− .16	+ .17	1.34	− 0.52	1.25	1.90	0.44	1.	− .26	15
− .16	+ .05	1.31	− 0.50	1.19	1.86	0.56	1.	− .24	19
− .16	+ .09	1.33	− 0.07	− 1.15	+ 1.84	0.63	1.	+ .19	21
− .21	+ .30	1.09	+ 1.29	+ 1.56	− 1.62	1.10	1.	+ 1.75	1892. Mar. 1
− .21	+ .12	1.06	+ 0.75	+ 1.54	− 1.67	− 1.04	1.	+ 1.21	2

D (1) *B. D.* − 0°, 258. ι Hydrae.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Oct. 16	F.	+ 10.7	+ 0.36	− 8 24.52	+ 3 15.01	+ 0 27.83	18.68
1891. Oct. 8	C.	+ 10.6	− .03	31.27	17.16	29.62	15.48
9	C.	+ 9.9	− .03	28.92	17.13	29.41	17.59
11	C.	+ 10.5	− .03	30.62	18.58	28.95	16.88
15	C.	− 3.0	− .03	32.21	22.05	27.90	17.71
19	C.	+ 2.3	− .03	28.66	19.45	26.74	17.50
21	C.	+ 1.9	− .03	− 8 29.74	+ 3 21.13	+ 0 26.10	17.46

I. α Piscium. α Leonis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Sep. 21	C.	+ 12.6	+ 0.36	+ 3 30.08	+ 3 17.59	+ 0 35.04	23.07
22	F.	+ 23.4	+ .27	31.89	13.17	35.03	20.36
23	C.	+ 14.1	+ .36	29.31	18.15	35.00	22.82
25	C.	+ 15.8	+ .27	32.34	15.18	34.93	23.72
26	F.	+ 5.0	+ .36	26.11	21.63	34.88	22.97
27	C.	+ 8.1	+ .27	26.96	21.26	34.81	23.30
28	F.	+ 11.7	+ .36	26.89	19.34	34.73	21.32
30	F.	+ 17.1	+ .36	30.41	15.87	34.56	21.20
Oct. 4	F.	+ 22.1	+ .36	34.69	13.04	34.08	22.17
26	F.	− 3.8	+ .44	28.95	23.26	28.63	21.28
31	C.	+ 2.5	+ .36	3 37.72	18.50	+ 0 26.77	23.35
1891. Mar. 4	F.	− 16.1	− .02	4 29.10	29.11	− 0 33.92	24.27
11	F.	− 12.3	− .02	32.44	25.41	34.74	23.09
1892. Feb. 25	C.	+ 5.4	− .02	35.57	20.93	32.54	23.94
Mar. 1	C.	− 11.6	− .02	29.64	27.77	33.55	23.84
2	C.	− 0.8	− .02	+ 4 34.10	+ 3 22.87	− 0 33.73	23.22

A peculiarly difficult and unsatisfactory pair to observe on account of the brightness of one of the stars and the duplicity of the other. α Piscium, although usually seen double, was observed as one mass.

D = 119° 55′ 19″.00

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″						
− 0.04	− 0.10	....	+ 0.46	− 1.36	+ 1.89	− 0.47	0.5	− 0.09	1890. Oct. 16
− .08	− .10	+ 1.26	+ 2.44	1.45	1.92	0.21	0.5	+ 1.89	1891. Oct. 8
− .08	− .04	1.24	+ 0.29	1.44	1.91	0.24	1.	− .26	9
− .08	− .08	1.25	+ 1.03	1.42	1.90	0.31	1.	+ .48	11
− .08	+ .17	1.26	− 0.06	1.37	1.89	0.44	1.	− .61	15
− .08	+ .05	1.24	+ 0.29	1.30	1.86	0.56	1.	− .26	19
− .08	+ .09	+ 1.25	+ 0.28	− 1.27	+ 1.85	− 0.62	1.	− .27	21

D = 120° 7′ 23″.00

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+ 0.21	− 0.24	− 0.21	+ 0.17	− 1.71	+ 1.84	+ 0.35	1.	+ 0.26	1890. Sept. 21
+ .21	− .26	....	....	....	....	....	0.	....	22
+ .21	− .24	.21	+ 0.42	1.71	1.86	0.31	1.	+ .53	23
+ .21	− .28	.22	+ 0.57	1.71	1.88	0.23	0.5	+ .66	25
+ .21	− .22	....	+ 0.04	1.71	1.88	0.19	0.5	+ .13	26
+ .21	− .15	.20	− 0.16	1.70	1.89	+ 0.16	0.5	− .07	27
+ .21	− .17	....	... .	....	....	....	0.	....	28
+ .21	− .22	....	... .	....	....	....	0.	....	30
+ .22	− .22	....	+ 0.88	1.66	1.91	− 0.08	0.5	+ .92	Oct. 4
+ .24	− .16	....	....	....	... .	....	0.	....	26
+ .24	− .15	.22	− 0.23	− 1.31	+ 1.73	0.94	1.0	− .30	31
+ .34	− .10	... .	− 1.51	+ 1.66	− 1.69	1.00	0.5	− 1.22	1891. Mar. 4
+ .34	− .15	....	− 0.28	1.70	1.85	0.78	0.5	+ .02	11
+ .61	− .13	.36	− 1.06	1.59	1.51	1.22	0.5	− .78	1892. Feb. 25
+ .62	− .11	.35	− 1.00	1.64	1.62	1.10	1.	− .71	Mar. 1
+ .62	− .14	− 0.36	− 0.04	+ 1.65	− 1.64	− 1.04	1.	+ .25	2

The weights above given are assigned upon the customary scale, but in view of the peculiar difficulties of observation presented by this pair, they have been multiplied by the factor ½ in the formation of the equations.

II. γ Ceti. *l* Leonis

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Oct. 16	F.	+ 10.0	+ 0.36	+ 5 11.26	+ 3 16.99	+ 0 33.80	(2.41)
20	F.	+ 5.1	+ .44	9.40	20.51	33.09	(3.44)
30	F.	− 2.6	+ .36	10.65	23.92	30.64	4.57
31	C.	+ 3.2	+ .36	16.31	18.06	30.34	5.07
Nov. 4	F.	+ 3.3	+ .36	17.42	17.94	29.05	4.77
11	C.	+ 0.7	+ .36	5 15.84	23.47	+ 26.45	5.12
1891. Mar. 10	C.	+ 7.1	− .02	6 20.39	17.28	− 33.11	4.54
11	F.	− 14.3	− .02	10.70	26.31	33.30	(3.69)
14	C.	− 25.4	− .02	6.31	32.91	33.81	5.39
15	C.	+ 3.5	− .02	6 19.86	19.45	− 33.96	5.33
Oct. 8	C.	+ 9.3	− .02	5 10.36	19.20	+ 34.74	4.28
9	C.	+ 10.7	− .02	12.38	18.39	34.67	5.42
11	C.	+ 9.9	− .02	9.15	20.37	34.48	(3.98)*a*
15	C.	− 3.5	− .02	7.00	23.30	33.99	4.76
19	C.	+ 1.9	− .02	11.36	21.14	33.33	5.81
21	C.	+ 1.5	− .02	8.70	22.84	32.95	4.47
28	C.	+ 7.7	− .02	15.86	18.56	31.28	5.68
Nov. 1	C.	− 5.4	− .02	5 8.41	26.55	+ 30.11	5.05
1892. Feb. 25	C.	+ 7.1	− .02	6 14.99	20.41	− 29.63	5.73
Mar. 1	C.	− 12.4	− .02	8.57	28.12	31.15	5.52
2	C.	− 1.6	− .02	14.40	23.28	31.42	6.24
8	C.	+ 8.8	− .02	23.67	14.40	32.85	5.20
11	C.	− 0.3	− .02	19.50	20.19	33.43	6.24
14	C.	− 14.9	− .02	9.49	29.92	33.92	5.47
15	C.	− 18.0	− .02	+ 6 8.67	+ 3 30.71	− 34.06	5.30

(*a*). γ Ceti at times distinctly double. Reject.

$D = 120° \; 9' \; 4''.50.$

μ	τ	φ (d)	n	f	A	B	p	v	Date.
′	′	′	′					′	
− 0.15	− 0.17	......	......	......	......	......	0.	......	1890. Oct. 16
.15	.22	......	......	......	......	......	0.	......	20
.16	.20	......	+ 0.29	− 1.50	+ 1.74	− 0.91	0.5	− 0.05	30
.16	.18	− 0.48	+ 0.25	1.49	1.73	0.94	1.	− .09	31
.16	.15	......	+ 0.04	1.42	1.68	1.07	0.5	− .30	Nov. 4
.16	.15	.47	+ 0.16	− 1.29	+ 1.55	1.27	1.	− .17	11
.22	.15	.70	+ 1.01	+ 1.62	− 1.83	0.81	0.5	+ .85	1891. Mar. 10
.22	.22	......	......	......	......	......	0.	......	11
.22	.16	.64	+ 0.13	1.65	1.89	0.67	1.	− .03	14
.22	.12	.70	+ 0.21	+ 1.66	− 1.90	0.62	1.	+ .06	15
.33	.21	.46	+ 1.22	− 1.70	+ 1.92	0.21	1.	+ .86	Oct. 8
.33	.17	.46	+ 0.04	1.69	1.91	0.24	1.	− .32	9
.33	.24	.46	......	......	......	......	0.	......	11
.33	.17	.45	+ 0.69	1.66	1.87	0.44	1.	+ .38	15
.34	.16	.46	− 0.35	1.63	1.86	0.54	1.	− .71	19
.34	.17	.45	+ 0.99	1.61	1.84	0.62	1.	+ .63	21
.34	.15	.47	− 0.22	1.53	1.77	0.85	1.	− .57	28
.34	.15	.45	+ 0.39	− 1.48	+ 1.72	0.97	1.	+ .04	Nov. 1
.40	.15	.68	0.00	+ 1.45	− 1.50	1.26	1.	− .17	1892. Feb. 25
.40	.17	.65	+ 0.20	1.53	1.62	1.10	1.	+ .04	Mar. 1
.40	.18	.68	− 0.48	1.54	1.64	1.07	1.	− .64	2
.40	.17	.71	+ 0.58	1.60	1.78	0.88	1.	+ .42	8
.40	.16	.70	− 0.48	1.63	1.85	0.78	0.5	− .63	11
.41	.17	.66	+ 0.27	1.66	1.89	0.67	1.	+ .12	14
.41	.14	.65	+ 0.40	+ 1.66	− 1.90	− 0.63	1.	+ .25	15

The duplication of γ Ceti was subsequently traced to the influence of a scratch upon the field lens of the eye piece.

III. 32 Eridani. 95 Leonis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	' "	' "	' "	"
1890. Nov. 11	C.	− 0.3	+ 0.36	− 4 51.59	+ 3 22.16	+ 0 31.76	2.69
13	C.	+ 2.9	+ .36	49.50	19.37	31.22	1.45
19	C.	+ 3.4	+ .36	47.93	20.28	29.37	2.08
21	C.	+ 3.0	+ .36	49.73	22.13	28.68	1.44
26	F.	− 2.1	+ .36	47.52	22.16	+ 26.80	1.80
1891. Mar. 14	C.	− 27.0	− .02	− 3 60.70	32.72	− 30.10	1.90
15	C.	+ 1.6	− .02	3 47.46	19.64	− 30.41	1.75
Oct. 9	C.	+ 10.3	− .02	− 4 50.02	17.86	+ 34.68	2.50
11	C.	+ 9.5	− .02	4 52.98	19.83	+ 34.95	1.77
1892. Mar. 14	C.	− 15.1	− .02	− 3 56.93	29.24	− 30.32	1.97
15	C.	− 19.0	− .02	58.33	30.40	30.62	1.43
20	C.	− 12.6	− .02	53.80	27.85	31.97	2.06
23	C.	− 1.3	− .02	46.26	21.47	32.67	2.52
24	C.	+ 11.1	− .02	40.69	16.59	32.89	2.99
25	C.	+ 12.1	− .02	− 3 38.22	+ 3 15.01	− 33.09	3.68

E (1) *α* Ceti. p^3 Leonis.

		div.	"	' "	' "	' "	"
1890. Nov. 27	C.	− 7.2	+ 0.35	− 5 14.97	+ 3 23.83	+ 0 20.90	30.11 (*a*)
1891. Mar. 10	C.	+ 5.2	− .02	4 11.81	16.88	− 30.02	35.03 (*b*)
23	C.	+ 1.7	− .02	4 16.47	20.69	− 32.38	31.82
Oct. 15	C.	− 3.7	− .02	5 23.91	22.78	+ 32.82	31.67
19	C.	+ 0.1	− .02	5 18.90	20.71	+ 32.43	34.22 (*c*)
21	C.	+ 0.6	− .02	5 20.52	22.15	+ 32.18	33.79
28	C.	+ 8.6	− .02	5 15.73	17.07	+ 31.00	32.32
1892. Mar. 1	C.	− 13.5	− .02	4 26.99	27.28	− 27.71	32.56
8	C.	+ 8.7	− .02	4 11.20	13.30	− 29.70	32.38
11	C.	− 0.2	− .02	− 4 15.09	+ 3 18.90	− 30.42	33.37

(*a*) Micrometer index loose and there is some doubt about the setting of the position circle on this night. (*b*) Defective observation. (*c*) *α* Ceti seen triple. See note to *γ* Ceti—*l* Leonis.

D = 119° 59′ 2″.50.

μ	τ	$\varphi\ (d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+ 0.03	+ 0.04	+ 0.40	− 0.66	− 1.55	+ 1.55	− 1.27	1.	− 0.79	1890. Nov. 11
.03	− .01	.40	+ 0.63	1.53	1.51	1.32	1.	+ .51	13
.03	+ .00	.40	− 0.01	1.44	1.38	1.47	1.	− .12	19
.03	+ .05	.40	+ 0.58	1.40	1.33	1.52	1.	+ .47	21
.03	+ .08	....	+ 0.59	− 1.31	+ 1.20	1.63	0.5	+ .49	26
.04	+ .32	.28	− 0.04	+ 1.47	− 1.89	0.67	1.	− .09	1891. Mar. 14
.04	+ .05	.25	+ 0.41	+ 1.49	− 1.90	0.64	1.	+ .46	15
.06	− .08	.40	− 0.38	− 1.69	+ 1.91	0.24	1.	− .32	Oct. 9
.06	− .11	.41	+ 0.37	− 1.71	+ 1.90	0.31	1.	+ .43	11
.08	+ .22	.28	− 0.05	+ 1.49	− 1.89	0.67	1.	− .21	1892. Mar. 14
.08	+ .25	.28	+ 0.46	1.50	1.90	0.64	1.	+ .30	15
.08	+ .18	.27	− 0.09	1.56	1.96	0.44	1.	− .26	20
.08	+ .04	.25	− 0.39	1.59	1.98	0.34	1.	− .56	23
.08	− .12	.23	− 0.68	+ 1.60	− 1.98	− 0.30	1.	− .85	24
+ .08	− .12	+ .23	....	....	....	....	0.	....	25

D = 119° 58′ 33″.50

″	″	″	″					″	
− 0.04	+ 0.18	+ 0.47	....	....	....	....	0.	....	1890. Nov. 27
.05	− .02	.30	− 1.76	+ 1.47	− 1.83	− 0.81	0.5	− 2.04	1891. Mar. 10
.05	+ .03	.32	+ 1.38	+ 1.58	− 1.98	0.34	1.	+ 1.11	23
.08	+ .08	.50	+ 1.33	− 1.60	+ 1.89	0.44	1.	+ .86	Oct. 15
.08	+ .04	.48	− 1.16	− 1.58	+ 1.86	0.56	0.5	− 1.63	19
.08	+ .04	.49	− 0.74	− 1.57	+ 1.84	0.62	1.	− 1.21	21
.08	− .04	.48	+ 0.82	− 1.52	+ 1.77	0.85	1.	+ .35	28
.10	+ .18	.34	+ 0.52	+ 1.36	− 1.62	1.10	1.	+ .23	1892. Mar. 1
.10	− .07	.30	+ 0.99	+ 1.46	− 1.79	0.88	1.	+ .71	8
− .10	+ .06	+ .32	− 0.15	+ 1.63	− 1.85	− 0.78	0.5	− .43	11

F (1) 10 Tauri. *υ* Leonis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	′ "	′ "	′ "	"
1890. Oct.16	F.	+ 9.4	+0.48	−2 57.86	+3 16.29	+0 32.91	51.82
30	F.	− 3.9	+ .35	64.01	22.56	32.02	50.92
Nov. 4	F.	+ 4.6	+ .35	55.41	16.25	31.24	52.43
10	F.	− 6.1	+ .35	63.28	24.39	29.98	51.44
11	C.	− 1.0	+ .22	60.39	22.05	29.75	51.63
12	F.	− 3.5	+ .35	61.51	22.12	29.49	50.45
13	C.	+ 2.9	+ .35	57.59	19.00	29.23	50.99
18	F.	+ 3.1	+ .35	54.68	19.88	27.79	[53.34]
19	C.	+ 2.4	+ .35	56.60	20.19	27.48	51.42
20	F.	+ 7.9	+ .35	53.30	17.07	27.15	51.27
21	C.	+ 2.6	+ .35	2 57.46	21.90	+ 26.82	51.61
1891. Mar 14	C.	−28.3	− .02	1 72.60	32.78	− 28.36	51.80
15	C.	+ 0.7	− .02	1 58.85	19.71	− 28.66	52.18
Oct. 21	C.	+ 0.4	− .02	2 63.48	22.27	+ 32.82	51.59
28	C.	+ 9.2	− .02	2 57.72	16.85	+ 32.29	51.40
1892. Mar.11	C.	0.0	− .02	1 58.15	18.78	− 27.69	52.92
14	C.	−15.3	− .02	68.42	28.97	28.58	51.97
15	C.	−19.7	− .02	69.52	30.32	28.85	51.93
20	C.	−12.9	− .02	65.66	27.62	30.12	51.82
23	C.	− 1.7	− .02	59.46	21.29	30.76	51.05
24	C.	+ 9.3	− .02	52.98	16.77	30.96	52.81
25	C.	+11.3	− .02	50.88	14.92	31.15	52.87
27	C.	+10.7	− .02	52.72	16.69	31.49	52.46
28	C.	+11.8	− .02	−1 53.80	+3 17.62	−0 31.65	52.15

D = 120° 0' 51".50

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″						
−0.16	−0.10	....	−0.06	−1.61	+1.89	−0.47	0.25	−0.08	1890. Oct. 16
.17	.00	....	+0.68	1.56	1.74	0.92	0.5	+ .66	30
.17	− .02	....	−0.74	1.53	1.68	1.07	0.5	− .75	Nov. 4
.18	+ .06	....	+0.18	1.47	1.57	1.24	0.5	+ .18	10
.18	+ .02	+0.16	−0.13	1.46	1.55	1.26	1.	− .13	11
.18	− .01	....	+1.24	1.44	1.53	1.29	0.5	+1.25	12
.18	− .04	.16	+0.57	1.43	1.51	1.32	1.	+ .58	18
.18	− .08	....	....	....	....	....	0.	....	18
.18	− .08	.16	+0.13	1.34	1.38	1.47	1.	+ .14	19
.18	− .16	....	+0.57	1.33	1.35	1.50	0.5	+ .58	20
.18	+ .02	.15	−0.10	−1.31	+1.33	1.52	1.	− .09	21
.25	+ .23	.08	−0.36	+1.39	−1.89	0.67	1.	− .18	1891. Mar. 14
.25	+ .03	.07	−0.53	+1.40	−1.90	0.64	1.	− 35	15
.38	− .01	.16	+0.14	−1.60	+1.84	0.62	1.	+ .12	Oct 21
.38	− .11	.16	+0.43	−1.54	+1.77	0.85	1.	+ .41	28
.46	.00	.07	−1.03	+1.35	−1.85	0.78	1.	− .85	1892. Mar. 11
.46	+ .16	.08	−0.25	1.40	1.89	0.68	1.	− .07	14
.46	+ .19	.08	−0.24	1.41	1.90	0.64	1.	− .06	15
.46	+ .13	.08	−0.07	1.48	1.96	0.45	1.	+ .11	20
.46	+ .01	.07	+0.83	1.51	1.98	0.34	1.	+1.01	23
.47	− .11	.06	−0.79	1.52	1.99	0.31	1.	− .61	24
.47	− .14	.06	−0.82	1.53	1.99	0.26	1.	− .64	25
.47	− .07	.06	−0.48	1.54	1.99	0.18	1.	− .30	27
−0.47	−0.08	+0.06	−0.16	+1.55	−2.00	−0.14	1.	+ .02	28

IV. μ Tauri. *c* Virginis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	' "	' "	' "	"
1890. Nov.12	F.	− 2.9	+0.36	+4 49.00	+3 22.72	+0 33.43	45.51
18	F.	+ 2.2	+ .36	50.39	21.26	32.08	44.09
19	C.	+ 2 5	+ .36	51.27	21.09	31.83	44.55
20	F.	+ 6.8	+ .36	55.92	18.45	31.56	46.29
21	C.	+ 1.0	+ .36	48.59	23.60	31.28	43.83
26	F.	− 3.1	+ .36	52.09	23.28	29.74	45.47
27	C.	− 7.5	+ .36	49.88	24.98	29.41	44.63
Dec.14	F.	− 9.5	+ .26	4 58.28	26.23	+ 22.38	47.15
1891. Mar.15	C.	− 1.0	− .02	5 50.43	21.51	− 27.87	44.05
Apr.16	C.	− 2.3	− .02	5 56.36	22.77	− 33.83	45.28
Oct. 28	C.	+10.0	− .02	4 52.07	17.61	+ 35.13	44.79
Nov.11	C.	− 1.5	− .02	4 48.08	22.14	+ 33.66	43.86
1892. Mar. 8	C.	+ 5.8	− .02	5 55.03	15.36	− 25.37	45.00
11	C.	+ 1.4	− .02	52.07	19.16	26.61	44.60
15	C.	−20.8	− .02	41.18	31.91	28.13	44.94
20	C.	−14.3	− .02	45.81	29.27	29.85	45.21
23	C.	− 2.6	− .02	52.37	22.75	30.78	44.32
24	C.	+ 8.0	− .02	57.86	18.27	31.07	45.04
25	C.	+ 9.2	− .02	59.84	16.76	31.35	45.23
27	C.	+ 9.6	− .02	57.99	18.22	31.88	44.31
28	C.	+ 9.3	− .02	57.45	19.34	32.13	44.64
Apr. 2	C.	+19.0	− .02	64.76	13.61	33.24	45.11
4	C.	+32.5	− .02	72.19	5.41	33.61	(*a*) 43.97
7	C.	+19.6	−0.02	+5 65.49	+3 13.44	−0 34.08	44.83

(*a*) Observed at the center of a barometric "Low." Pressure 28.30 inches. Very bad seeing. Reject.

$D = 120° 8' 44''.50$

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.23	−0.15	....	....	....	....	....	0.	....	1890. Nov. 12
.24	.16	....	+0.33	−1.56	+1.40	−1.45	0.5	+0.27	18
.24	.15	−0.40	+0.26	1.55	1.38	1.47	1.	+ .20	19
.24	.13	....	....	....	....	....	0.	....	20
.24	.11	.40	+0.94	1.53	1.33	1.52	1.	+ .88	21
.24	.13	....	....	....	....	....	0.	....	26
.24	.13	.40	+0.16	−1.44	+1.17	1.65	1.	+ .11	27
.25	.12	....	....	....	....	....	0.	....	Dec. 14
.32	.12	.59	+0.84	+1.36	−1.90	−0.63	1.	+ .94	1891. Mar. 15
.34	.16	.61	−0.35	+1.65	−1.98	+0.12	1.	− .25	Apr. 6
.49	.18	.41	−0.19	−1.72	+1.77	−0.85	1.	− .27	Oct. 28
.50	.17	.40	+0.71	−1.64	+1.55	1.26	1.	+ .64	Nov. 11
.59	.16	.61	−0.32	+1.24	−1.79	0.88	1.	− .22	1892. Mar. 8
.59	.14	.60	+0.05	1.30	1.85	0.78	1.	+ .15	11
.59	.12	.56	−0.35	1.38	1.90	0.63	1.	− .25	15
.60	.13	.58	−0.60	1.47	1.96	0.45	1.	− .50	20
.60	.15	.60	+0.33	1.51	1.98	0.34	1.	+ .43	23
.60	.20	.61	−0.33	1.52	1.98	0.31	1.	− .23	24
.60	.20	.62	−0.51	1.53	1.98	0.26	1.	− .41	25
.60	.14	.61	+0.34	1.56	1.99	0.18	1.	+ .44	27
.60	.14	.61	+0.01	1.56	2.00	−0.14	1.	+ .12	28
.61	.20	.63	−0.39	1.62	2.00	+0.02	1.	− .28	Apr. 2
.61	.25	.67	....	....	....	....	0.	....	4
+0.61	−0.15	−0.63	−0.16	+1.66	−1.98	+0.18	1.	− .06	7

V. π^5 **Orionis.** δ **Virginis.**

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	′ "	′ "	′ "	"
1890. Nov. 4	F.	+ 3.8	+0.36	+1 49.46	+3 16.96	+0 34.77	41.55
10	F.	− 7.4	.36	42.66	25.58	34.57	43.17
11	C.	− 2.8	.36	45.18	23.24	34.49	43.27
12	F.	− 2.1	.36	47.34	21.94	34.42	44.06
13	C.	+ 2.9	.36	48.19	19.78	34.32	42.65
18	F.	+ 2.1	.24	46.92	20.89	33.71	41.76
19	C.	+ 2.2	.36	48.39	20.73	33.56	43.04
21	C.	− 0.1	.36	45.97	23.65	33.21	43.19
27	C.	− 7.5	.36	46.58	24.49	31.94	43.37
Dec. 14	F.	− 9.9	+ .36	1 51.53	25.91	+ 26.45	44.25
1891. Apr. 4	C.	− 5.0	− .02	2 50.28	24.19	− 30.73	43.72
6	C.	− 2.7	.02	52.52	22.57	31.26	43.81
7	F.	+ 3.8	.02	54.62	20.64	31.51	43.73
12	C.	+22.4	.02	2 63.82	12.68	− 32.35	43.83
Nov. 11	C.	− 2.5	.02	1 46.91	22.19	+ 34.52	43.59
28	C.	−35.7	.02	1 33.14	37.86	+ 31.76	42.74
1892. Mar. 27	C.	+ 9.0	.02	2 53.82	18.08	− 28.46	43.42
28	C.	+ 6.7	.02	52.50	19.87	28.79	43.56
Apr. 2	C.	+16.7	.02	59.51	14.06	30.36	43.19
7	C.	+ 8.9	.02	61.16	13.34	31.70	42.78
9	C.	− 0.1	.02	52.68	21.66	32.17	42.15
10	C.	+ 2.6	.02	54.15	20.79	32.39	42.53
14	C.	+10.4	.02	58.37	17.95	33.17	43.13
15	C.	+15.8	−0.02	+2 61.04	+3 15.69	−0 33.34	43.87

D=120° 5′ · 44″.00.

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.41	−0.08	....	....	....	....	....	0.	....	1890. Nov. 4
.42	.08	....	+0.49	−1.69	+1.57	−1.25	0.5	+0.19	10
.42	.08	−0.06	+0.45	1.68	1.55	1.28	1.	+ .15	11
.42	.08	.....	−0.40	1.68	1.53	1.30	0.5	− .70	12
.42	.11	.06	+1.10	1.68	1.51	1.32	1.	+ .81	13
.43	.10	....	....	....	....	....	0.	....	18
.43	.10	.06	+0.69	1.64	1.38	1.47	1.	+ .41	19
.43	.05	.06	+0.49	1.64	1.33	1.52	1.	+ .21	21
.44	.05	.06	+0.30	−1.56	+1.17	−1.65	1.	+ .03	27
.46	.06	....	....	....	....	....	0.	....	Dec. 14
.62	.07	.14	−0.13	+1.50	−1.99	+0.09	1.	− .26	1891. Apr. 4
.62	.10	.14	−0.19	1.53	1.98	0.16	1.	− .32	6
.62	.09	....	−0.26	1.54	1.98	0.18	1.	− .39	7
.63	.27	.16	−0.03	+1.59	−1.95	+0.34	1.	− .16	12
.91	− .10	.06	−0.34	−1.69	+1.55	−1.26	1.	− .64	Nov. 11
.93	+ .01	.04	+0.36	−1.55	+1.14	1.67	1.	+ .09	28
1.10	− .11	.15	−0.26	+1.39	−1.99	0.19	1.	− .38	1892. Mar. 27
1.10	.10	.15	−0.41	1.41	1.99	−0.14	1.	− .53	28
1.11	.20	.16	+0.06	1.49	2.00	+0.02	1.	− .06	Apr. 2
1.11	.14	.16	+0.41	1.55	1.98	0.18	1.	+ .28	7
1.11	.10	.15	+0.99	1.57	1.97	0.25	1.	+ .86	9
1.11	.10	.15	+0.61	1.58	1.97	0.28	1.	+ .48	10
1.12	.18	.16	+0.09	1.62	1.93	0.41	0.5	− .04	14
+1.12	−0.15	−0.16	−0.18	+1.63	−1.93	+0.44	1.	−0.31	15

$\varDelta$ (2) *o* Orionis. B. D. + 2°, 2664.

Date.	Obs'r.	Temp.	K	d	R	A	$\varDelta$
		div.	″	′ ″	′ ″	′ ″	″
1891. Mar.15	C.	− 3.6	−0.02	−4 22.51	+3 21.63	−0 19.58	39.52
Apr. 6	C.	− 3.0	.02	4 13.35	22.06	− 28.69	40.00
Nov.28	C.	−36.7	.02	5 31.73	37.66	+ 33.12	39.03
29	C.	−26.8	.02	24.94	32.34	32.95	40.33
Dec. 1	C.	+ 1.1	.02	10.64	18.38	32.57	40.29
11	C.	− 3.9	.02	5 14.58	24.75	+ 30.05	40.20
1892. Mar.13	C.	−19.3	.02	4 32.48	30.71	− 18.95	39.26
15	C.	−23.0	.02	32.64	31.35	19.94	38.75
20	C.	−15.0	.02	27.79	28.50	23.29	38.40
23	C.	− 3.1	.02	17.85	21.94	23.63	40.45
24	C.	+ 7.4	.02	13.85	17.51	24.05	40.59
25	C.	+ 8.5	.02	11.84	16.00	24.47	39.67
27	C.	+ 8.5	.02	11.89	17.67	25.30	40.46
28	C.	+ 5.5	.02	13.53	19.67	25.70	40.42
Apr. 2	C.	+16.1	.02	5.08	13.63	27.57	40.96
7	C.	+18.3	.02	5.02	12.99	29.25	38.70
9	C.	− 0.4	−0.02	−4 11.08	+3 21.13	−0 29.85	40.18

D = 119° 58′ 40″.00

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.11	+0.10	+0.33	−0.06	+0.96	−1.90	−0.64	1.	+0.32	1891. Mar. 15
.11	+ .15	.31	−0.57	+1.40	−1.99	+0.16	1.	− .10	Apr. 6
.17	+ .37	.52	−0.09	−1.62	+1.14	−1.67	1.	+ .23	Nov. 28
.17	+ .30	.50	−1.30	1.61	1.12	1.69	1.	− .98	29
.17	− .02	.46	−0.90	1.59	1.06	1.78	0.5	− .57	Dec. 1
.17	+ .09	.47	−0.93	−1.47	+0.76	1.90	1.	− .59	11
.20	+ .25	.36	−0.07	+0.93	−1.87	0.71	1.	+ .40	1892. Mar. 13
.20	+ .27	.36	+0.42	0.98	1.90	0.64	1.	+ .90	15
.20	+ .20	.34	+0.86	1.09	1.96	0.45	1.	+1.34	20
.20	+ .06	.32	−1.03	1.15	1.98	0.34	1.	− .55	23
.20	− .09	.31	−1.01	1.17	1.99	0.30	1.	− .53	24
.20	− .10	.31	−0.18	1.19	1.99	0.26	1.	+ .30	25
.20	− .04	.31	−0.93	1.23	2.00	0.18	1.	− .46	27
.20	− .01	.31	−0.92	1.25	2.00	−0.14	1.	− .45	28
.20	− .20	.29	−1.25	1.35	2.00	+0.02	1.	− .88	Apr. 2
.20	− .14	.29	+0.95	1.43	1.98	0.18	1.	+1.42	7
+0.20	+0.03	+0.30	−0.71	+1.46	−1.97	+0.25	1.	− .25	9

VI. ϑ Can. Maj. ε Bootis.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	' "	' "	' "	"
1890. Nov.10	F.	− 7.9	+0.36	−5 16.05	+3 25.48	+0 34.30	44.09
11	C.	− 2.6	+ .36	14.44	23.15	34.48	43.50
12	F.	− 1.4	+ .36	12.12	21.31	34.56	44.11
18	F.	+ 2.1	+ .36	11.90	20.59	35.13	44.18
19	C.	+ 2.5	+ .36	11.40	20.26	35.18	44.40
21	C.	+ 0.3	+ .36	14.88	23.24	35.26	43.96
27	C.	− 7.5	+ .36	5 16.91	24.12	+ 35.24	42.81
1891. Apr. 4	C.	− 5.0	− .02	3 76.45	23.88	− 23.72	43.69
7	F.	+ 1.9	− .02	71.04	20.99	25.03	44.90
12	C.	+21.3*	− .02	61.58	12.73	27.06	44.07
15	F.	+13.0	− .02	64.26	16.90	28.19	44.48
18	C.	+22.2	− .02	59.85	12.86	29.23	43.76
19	F.	+13.0	− .02	59.19	12.72	29.56	43.95
23	C.	+24.2	− .02	55.65	11.00	30.80	44.58
24	C.	+26.4	− .02	55.85	10.84	31.09	43.88
25	C.	+34.8	− .02	52.95	8.35	31.37	44.01
26	C.	+40.4	− .02	3 51.13	6.56	− 31.64	43.77
Nov.11	C.	− 3.4	− .02	5 12.36	22.32	+ 34.40	44.34
28	C.	−37.4	− .02	31.07	38.35	35.21	42.47
29	C.	−26.8	− .02	24.22	32.70	35.16	43.70
Dec. 6	C.	−21.0	− .02	19.96	28.67	34.50	43.19
9	C.	+ 3.9	− .02	7.84	18.10	34.05	44.29
10	C.	− 0.3	− .02	14.15	23.53	33.88	43.24
11	C.	− 4.5	− .02	5 15.25	25.62	+ 33.71	44.06
1892. Apr.10	C.	+ 2.1	− .02	3 69.67	20.59	− 26.57	44.33
14	C.	+10.2	− .02	64.51	17.75	28.08	45.14
15	C.	+13.9	− .02	63.20	15.92	28.45	44.25
22	C.	+23.5	−0.02	−3 56.45	+3 11.57	− 30.72	44.38

D = 119° 58′ 44″.00

μ	r	$\varphi\ (d)$	n	f	A	B	p	v	Date.
″	″	″	″						
−0.07	+0.12	....	−0.14	−1.68	+1.57	−1.25	0.5	−0.11	1890. Nov. 10
.07	+ .08	+0.47	+0.02	1.68	1.55	1.27	1.	+ .05	11
.07	+ .07	....	−0.11	1.69	1.53	1.39	0.5	− .08	12
.07	+ .02	....	−0.13	1.72	1.40	1.45	0.5	− .09	18
.07	+ .02	.46	−0.81	1.72	1.37	1.47	1.	− .76	19
.07	+ .09	.47	−0.45	1.72	1.33	1.52	1.	− .40	21
.08	+ .13	.48	+0.66	−1.72	+1.17	−1.65	1.	+ .72	27
.10	+ .10	.32	−0.01	+1.15	−1.99	+0.09	1.	+ .22	1891. Apr. 4
.10	+ .03	....	−0.83	1.22	1.98	0.18	0.5	− .60	7
.10	− .28	.28	+0.03	1.32	1.96	0.34	1.	+ .25	12
.10	− .19	....	−0.14	1.38	1.93	0.44	0.5	+ .08	15
.10	− .27	.28	+0.33	1.43	1.90	0.54	1.	+ .54	18
.11	− .12	....	+0.28	1.45	1.89	0.57	0.5	+ .49	19
.11	− .30	.27	−0.39	1.51	1.85	0.69	1.	− .18	23
.11	− .31	.27	+0.27	1.52	1.83	0.72	1.	+ .48	24
.11	− .34	.26	+0.18	1.54	1.82	0.75	1.	+ .38	25
.11	− .65	.26	+0.73	+1.54	−1.81	+0.78	1.	+ .93	26
.15	+ .06	.47	−0.90	−1.68	+1.55	−1.27	1.	− .87	Nov 11
.16	+ .40	.52	....	....	....	....	0.	....	28
.16	+ .38	.50	−0.37	1.72	1.12	1.69	1.	− .31	29
.16	+ .28	.49	+0.20	1.69	0.92	1.83	1.	+ .27	Dec. 6
.16	.00	.45	−0.58	1.66	0.82	1.87	1.	− .51	9
.16	+ .03	.47	+0.42	1.65	0.79	1.88	1.	+ .50	10
.16	+ .10	.47	−0.47	−1.64	+0 76	−1.90	1.	− .39	11
.19	+ .02	.30	−0.46	+1.30	−1.97	+0.28	1.	− .24	1892. Apr. 10
.19	− .12	.29	−1.13	1.37	1.94	0.41	0.5	− .90	14
.19	− .11	.29	−0.24	1.39	1.93	0.44	1.	− .02	15
−0.19	−0.20	+0.27	−0.26	+1.51	−1.86	+0.66	1.	− .05	23

VII. ε Tauri. ε Corvi.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ ″	′ ″	′ ″	″
1890. Nov.11	C.	− 3.0	+0.35	−3 32.29	+3 22.26	+0 31.67	21.99
18	F.	+ 2.8	+ .35	26.99	19.49	30.40	23.25
19	C.	+ 3.2	+ .35	27.25	18.94	30.19	22.28
20	F.	+11.1	+ .35	24.39	15.28	29.96	21.20
21	C.	+ 0.8	+ .35	30.24	22.19	29.73	22.03
27	C.	− 7.5	+ .35	28.79	23.06	28.11	22.73
Dec. 14	F.	− 9.9	+ .35	3 25.07	24.44	+ 21.88	21.60
1891. Mar.15	C.	− 5.0	− .03	2 35.07	21.60	− 25.04	21.46
Apr. 4	C.	− 5.3	− .03	30.40	22.94	30.69	21.82
6	C.	− 3.3	− .03	28.32	21.53	31.06	22.12
12	C.	+20.3	− .03	17.34	12.04	31.95	22.72
15	F.	+11.8	− .03	21.37	16.29	32.28	22.61
18	C.	+21.9	− .03	17.44	11.97	32.51	21.99
19	F.	+22.1	− .03	17.55	12.45	32.57	22.30
22	C.	+26.0	− .03	14.93	9.40	32.70	21.74
23	C.	+21.5	− .03	16.57	11.02	32.72	21.70
24	C.	+25.1	− .03	15.84	10.26	32.73	21.66
25	C.	+33.0	− .03	13.19	8.11	32.73	22.16
26	C.	+39.2	− .03	11.12	5.92	32.73	22.04
27	C.	+31.3	− .03	14.23	8.86	32.71	21.89
28	C.	+26.6	− .03	15.69	11.17	32.69	22.66
29	C.	+38.9	− .03	2 9.61	4.25	− 32.65	21.96
Nov.11	C.	− 3.9	− .03	3 30.98	21.53	+ 31.70	22.22
28	C.	−38.1	− .03	44.29	37.65	27.89	21.23
29	C.	−26.8	− .03	37.59	31.61	27.58	21.57
Dec. 6	C.	−21.4	− .03	31.64	27.83	25.20	21.36
9	C.	+ 3.1	− .03	19.42	17.43	24.05	22.03
10	C.	− 0.9	− .03	25.75	22.74	23.66	20.62
11	C.	− 5.4	−0.03	26.36	24.95	23.25	21.81

$D = 120° \ 0' \ 22''.50$

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.16	+0.06	+0.21	+0.08	−1.55	+1.55	−1.27	1.	−0.29	1890. Nov. 11
.16	.00	... .	−0.91	1.49	1.40	1.45	0.5	−1.27	18
.16	.00	.20	−0.09	1.48	1.38	1.47	1.	− .45	19
.16	.12	....	+1.02	1.47	1.35	1.49	0.5	+ .67	20
.16	.07	.21	+0.06	1.46	1.33	1.52	1.	− .29	21
.17	.10	.21	−0.71	1.38	1.17	1.65	1.	−1.05	27
.18	.12	....	+0.60	−1.07	+0.65	1.94	0.5	+ .29	Dec. 14
.22	.09	.12	+0.81	+1.22	−1.90	−0.65	1.	+ .63	1891. Mar. 15
.23	.08	.11	+0.26	1.50	1.98	+0.09	1.	+ .09	Apr. 4
.23	+ .04	.11	0.00	1.52	1.98	0.15	1.	− .18	6
.24	− .27	.09	−0.28	1.56	1.96	0.34	1.	− .46	12
.24	.07	....	−0.28	1.57	1.93	0.44	0.5	− .46	15
.24	.26	.09	+0.44	1.59	1.89	0.54	1.	+ .25	18
.24	.26	....	+0.22	1.59	1.89	0.57	0.5	+ .03	19
.24	.31	.08	+0.75	1.59	1.86	0.66	1.	+ .56	22
.24	.27	.09	+0.74	1.60	1.84	0.69	1.	+ .55	23
.25	.29	.09	+0.79	1.60	1.83	0.72	1.	+ .59	24
.25	.29	.08	+0.30	1.60	1.82	0.75	1.	+ .09	25
.25	.60	.08	+0.73	1.60	1.81	0.78	1.	+ .52	26
.25	.30	.08	+0.58	1.60	1.80	0.80	1.	+ .39	27
.25	.31	.09	−0.19	1.59	1.78	0.83	1.	− .40	28
.25	− .49	.08	+0.70	+1.59	−1.76	+0.86	0.5	+ .49	29
.35	+ .04	.21	−0.32	−1.55	+1.55	−1.27	1.	− .68	Nov. 11
.36	.34	.24	+0.34	1.36	1.14	1.67	1.	+ .01	28
.36	.27	.22	+0.08	1.35	1.12	1.69	1.	− .25	29
.36	+ .21	.21	+0.36	1.23	0.92	1.83	1.	+ .04	Dec. 6
.36	− .01	.19	−0.07	1.17	0.82	1.87	1.	− .39	9
.36	+ .03	.20	+1.29	1.15	0.79	1.88	1.	+ .98	10
+ .36	+ .07	+0.20	+0.06	1.13	+0.76	−1.90	1.	− .25	11

VIII. 119 Tauri. α Virginis.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ ″	′ ″	′ ″	″
1890. Nov. 18	F.	+ 2.3	+0.35	+3 11.50	+3 20.92	+0 35.07	7.84
19	C.	+ 3.0	.35	11.69	20.41	35.01	7.46
21	C.	− 0.7	.35	7.90	24.02	34.86	7.13
27	C.	− 7.5	+ .35	3 8.85	24.47	+ 34.15	7.32
1891. Apr. 4	C.	− 5.9	− .02	4 10.92	24.61	− 28.05	7.46
6	C.	− 3.7	.02	13.90	23.01	28.76	8.13
7	F.	− 0.4	.02	14.73	22.23	29.11	7.83
11	F.	+ 9.8	.02	21.09	17.74	30.39	8.42
12	C.	+19.3	.02	26.10	13.70	30.69	9.00
15	F.	+10.9	.02	22.01	18.00	31.53	8.46
18	C.	+21.6	.02	27.35	13.53	32.23	8.58
19	F.	+20.6	.02	26.58	14.40	32.52	8.44
22	C.	+25.2	.02	30.33	11.10	33.17	8.24
23	C.	+20.2	.02	28.53	12.93	33.36	8.08
24	C.	+23.6	.02	29.87	12.15	33.54	8.46
25	C.	+31.7	.02	32.68	9.96	33.71	8.95
26	C.	+37.7	.02	34.04	7.77	33.88	7.91
27	C.	+30.6	.02	30.99	10.51	34.03	7.45
28	C.	+25.0	.02	29.13	13.11	34.18	8.04
29	C.	+37.2	.02	36.79	6.15	34.32	8.60
30	C.	+26.8	.02	31.49	10.79	34.45	7.81
May 2	C.	+11.7	.02	26.75	16.10	34.67	8.16
5	C.	+17.4	.02	25.74	16.87	34.94	7.65
6	C.	+22.4	.02	27.96	15.02	35.00	7.96
7	C.	+32.0	.02	4 33.13	10.61	− 35.06	8.66
Nov. 28	C.	−38.2	− .02	2 53.94	39.22	+ 34.03	7.17

D=120° 7′ 8″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.05	−0.12	....	+0.23	−1.71	+1.40	−1.45	0.5	−0.26	1890. Nov. 18
.05	.13	−0.17	+0.79	1.71	1.38	1.47	1.	+ .30	19
.05	.07	.17	+1.06	1.70	1.33	1.52	1.	+ .58	21
.06	.07	.17	+0.86	−1.67	+1.17	−1.65	1.	+ .38	27
.08	.09	.30	+0.85	+1.87	−1.99	+0.09	1.	+ .53	1891. Apr. 4
.08	.11	.30	+0.20	1.41	1.98	0.15	1.	− .13	6
.08	.10	....	+0.19	1.43	1.98	0.18	0.5	− .15	7
.08	.14	......	−0.36	1.49	1.96	0.31	0.5	− .70	11
.08	.27	.34	−0.47	1.50	1.95	0.34	0.5	− .81	12
.08	.14	....	−0.40	1.54	1.93	0.44	0.5	− .74	15
.08	.24	.32	−0.10	1.57	1.90	0.54	1.	− .45	18
.08	.24	....	−0.28	1.59	1.89	0.57	0.5	− .63	19
.08	.26	.35	+0.29	1.62	1.86	0.66	1.	− .06	22
.08	.26	.35	+0.45	1.63	1.84	0.69	1.	+ .09	23
.08	.25	.35	+0.06	1.64	1.83	0.72	1.	− .30	24
.08	.19	.36	−0.48	1.65	1.82	0.75	1.	− .84	25
.08	.46	.36	+0.83	1.65	1.80	0.77	1.	+ .47	26
.08	.21	.35	+1.03	1.66	1.79	0.80	1.	+ .67	27
.08	.23	.35	+0.46	1.67	1.78	0.83	1.	+ .10	28
.08	.35	.37	+0.04	1.68	1.76	0.86	1.	− .32	29
.08	.18	.35	+0.64	1.68	1.75	0.89	1.	+ .28	30
.08	.18	.34	+0.28	1.69	1.71	0.95	1.	− .08	May 2
.08	.15	.34	+0.76	1.71	1.66	1.03	1.	+ .40	5
.08	.22	.34	+0.52	1.71	1.64	1.06	0.5	+ .15	6
.08	.23	.36	−0.15	+1.71	−1.62	+1.09	1.	− .52	7
+ .12	− .03	− .15	+0.89	−1.66	+1.14	−1.67	1.	+ .41	Nov. 28

VIII. 119 Tauri. α Virginis.—Continued.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	' "	' "	' "	"
1891. Nov. 29	C.	−26.4	−0.02	+2 59.47	+3 32.76	+0 33.87	(*a*) 6.08
Dec. 6	C.	−22.3	− .02	66.42	29.60	32.43	8.43
9	C.	+ 2.9	− .02	76.57	18.96	31.66	7.17
10	C.	− 0.8	− .02	72.38	24.14	31.38	7.88
11	C.	− 5.9	− .02	70.24	26.55	31.10	7.87
17	C.	−15.2	− .02	68.12	29.83	+0 29.17	7.10

(*a*) Observer notes: Star images very diffuse and bisections unsatisfactory.

D = 120° 7′ 8″.00.

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.12	−0.03	−0.16	....	....	....	....	0.	....	1891. Nov. 29
.12	.03	.17	−0.35	−1.58	+0.92	−1.83	1.	−0.82	Dec. 6
.12	.13	.18	+1.02	1.55	.82	1.87	1.	+ .55	9
.12	.12	.17	+0.29	1.53	.79	1.88	1.	− .17	10
.12	.09	.17	+0.27	1.52	.76	1.90	1.	− .19	11
+0.12	−0.05	−0.17	+1.00	−1.43	+0.56	−1.97	1.	+ .55	17

B (2) 19 Monocerotis. 110 Virginis.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1891. Mar. 15	C.	− 6.5	−0.02	+0 34.02	+3 23.11	−0 5.54	51.57
Apr. 4	C.	− 6.8	.02	44.11	24.29	16.92	51.46
6	C.	− 3.7	.02	47.09	22.43	17.97	51.53
11	F.	+ 8.9	.02	54.25	17.40	20.48	51.15
18	C.	+21.3	.02	62 14	13.02	23.72	51.42
23	C.	+19.4	.02	64.54	12.67	25.83	51.36
24	C.	+22.8	.02	66.02	11.80	26.23	51.57
25	C.	+30.6	.02	68.12	9.79	26.62	51.27
26	C.	+36.7	.02	71.80	7.52	27.00	(*a*) 52.30
27	C.	+30.3	.02	68.87	10.07	27.38	51.54
28	C.	+24.0	.02	66.71	12.88	27.75	51.77
30	C.	+25.5	.02	69.18	10.87	28.46	51.57
May 2	C.	+10.9	.02	+ 65.09	15.79	− 29.14	51.72
Nov. 28	C.	−38.1	.02	− 22.28	38.56	+ 34.67	50.93
29	C.	−25.9	.02	15.94	31.94	34.76	(*b*) 50.74
Dec. 6	C.	−22.7	.02	12.78	29.13	35.12	51.45
9	C.	+ 2.6	.02	1.71	18.53	35.11	51.91
10	C.	− 1.0	.02	7.56	23.68	35.08	51.18
11	C.	− 5.8	.02	9.75	25.93	35.04	51.20
17	C.	−15.2	−0.02	12.83	29.20	+ 34.59	50.94

(*a*). Observer notes: Large fire to windward. Air full of smoke. Images diffuse and unsteady.
(*b*). Observer notes: Diffuse. Observation unsatisfactory.

D = 120° 3′ 51″.50

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.07	−0.01	0.00	−0.13	+0.25	−1.90	−0.63	1.	−0.18	1891. Mar. 15
.08	.00	− .01	−0.03	0.83	1.99	+0.09	1.	− .08	Apr. 4
.08	− .04	− .01	−0.06	0.88	1.99	0.15	1.	− .11	6
.08	− .10	....	+0.37	1.00	1.96	0.31	0.5	+ .31	11
.08	− .24	− .02	+0.26	1.16	1.90	0.54	1.	+ .20	18
.08	− .26	− .02	+0.34	1.26	1.85	0.69	1.	+ .26	23
.08	− .24	− .02	+0.11	1.28	1.83	0.72	1.	+ .02	24
.08	− .23	− .02	+0.40	1.30	1.82	0.75	1.	+ .31	25
.08	− .51	− .02	−0.35	1.32	1.81	0.77	0.5	− .46	26
.08	− .25	− .02	+0.15	1.34	1.79	0.80	1.	+ .06	27
.08	− .25	− .02	−0.08	1.36	1.78	0.83	1.	− .17	28
.08	− .20	− .02	+0.07	1.39	1.75	0.89	1.	− .02	30
.08	− .14	− .02	−0.14	+1.43	−1.71	+0.95	1.	− .23	May 2
.12	− .11	.00	+0.56	−1.69	+1.14	−1.67	1.	+ .35	Nov. 28
.12	− .07	.00	+0.71	1.70	1.12	1.69	0.5	+ .50	29
.12	− .06	.00	−0.01	1.72	0.92	1.83	1.	− .21	Dec. 6
.12	− .07	.00	−0.46	1.72	0.82	1.87	1.	− .66	9
.12	− .05	.00	+0.25	1.71	0.79	1.88	1.	+ .06	10
.12	− .04	.00	+0.23	1.71	0.76	1.90	1.	+ .03	11
+0.12	+ .06	.00	+0.38	−1.69	+0.56	−1.97	1.	+ .20	17

IX. γ Geminorum. 109 Virginis.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1890. Nov.27	C.	− 7.5	+0.36	−0 68.21	+3 24.56	+0 34.87	51.58
Dec. 14	F.	−10.3	+ .44	70.96	26.00	+ 33.14	[48.62]
1891. Apr. 4	C.	− 7.1	− .02	11.57	25.08	− 22.26	51.23
7	F.	− 1.6	− .02	7.80	22.81	23.62	51.37
15	F.	+ 9.9	− .02	− 0.36	18.47	26.88	51.21
18	C.	+21.0	− .02	+ 5.33	13.85	27.98	51.18
19	F.	+19.4	− .02	4.06	14.58	28.33	[50.29]
22	C.	+24.9	− .02	9.44	11.34	29.33	51.43
23	C.	+18.7	− .02	7.56	13.62	29.64	51.52
24	C.	+22.3	− .02	8.84	12.68	29.95	51.55
25	C.	+29.4	− .02	11.13	10.92	30.25	51.78
26	C.	+35.8	− .02	14.14	8.50	30.54	52.08
27	C.	+30.1	− .02	11.14	10.90	30.81	51.21
28	C.	+23.4	− .02	9.33	13.72	31.08	51.95
29	C.	+35.2	− .02	17.83	6.88	31.34	*a* [53.35]
30	C.	+24.7	− .02	11.63	12.01	31.60	52.02
May 2	C.	+10.3	− .02	6.64	16.71	32.08	51.25
5	C.	+16.5	− .02	6.73	17.28	32.73	51.26
6	C.	+20.8	− .02	8.53	15.62	32.92	51.21
7	C.	+29.9	− .02	13.13	11.45	33.12	51.44
8	C.	+36.8	− .02	17.19	7.92	33.30	51.79
11	C.	+31.4	− .02	+ 14.42	10.86	− 33.78	51.48
Nov.28	C.	−37.8	− .02	− 83.31	39.10	+ 34.85	50.62
29	C.	−25.8	− .02	76.21	32.41	34.83	51.01
Dec. 6	C.	−23.1	− .02	73.60	29.97	34.36	51.71
9	C.	+ 2.1	− .02	62.44	19.45	34.01	51.00
10	C.	− 1.5	− .02	67.39	24.64	33.86	51.09
11	C.	− 5.7	− .02	69.89	26.57	33.71	50.87
17	C.	−15.4	−0.02	− 71.59	+ 30.00	+ 32.58	50.97

(*a*) Defective meteorological record. Thermometer reading extrapolated.

$D = 120° \; 2' \; 51''.50$

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
"	"	"	"					"	
+0.13	+0.04	+0.02	−0.27	−1.70	+1.17	−1.65	1.	−0.41	1890. Nov. 27
.14	+ .04	....	....	....	....	....	0.	....	Dec. 14
.18	+ .03	.00	+0.05	+1.09	−1.99	+0.09	1.	+ .06	1891. Apr. 4
.18	− .01	....	−0.04	1.15	1.98	0.18	0.5	− .03	7
.19	.08	....	+0.18	1.31	1.93	0.44	0.5	+ .18	15
.19	.25	.00	+0.38	1.37	1.90	0.54	1.	+ .37	18
.19	.25	....	....	....	....	....	0.	....	19
.19	.28	.00	+0.16	1.44	1.86	0.66	1.	+ .15	22
.19	.25	.00	+0.04	1.45	1.85	0.69	1.	+ .03	23
.19	.26	.00	+0.02	1.47	1.83	0.72	1.	.00	24
.19	.24	.00	−0.23	1.48	1.82	0.75	1.	− .25	25
.19	.52	.00	−0.25	1.50	1.81	0.77	0.5	− .27	26
.19	.26	.00	+0.36	1.51	1.79	0.80	1.	+ .34	27
.19	.25	.00	+0.39	1.52	1.78	0.83	1.	− .41	28
.19	.42	.00	....	....	....	....	0.	....	29
.19	.20	.00	−0.51	1.55	1.75	0.89	1.	− .53	30
.19	.13	.00	+0.19	1.56	1.72	0.95	1.	+ .17	May 2
.20	.12	.00	+0.16	1.59	1.67	1.03	1.	+ .13	5
.20	.22	.00	+0.31	1.61	1.65	1.06	1.	+ .28	6
.20	.27	.00	+0.13	1.62	1.63	1.09	1.	+ .10	7
.20	.38	.00	−0.11	1.63	1.61	1.11	1.	− .14	8
.20	− .23	.00	+0.05	+1.65	−1.55	+1.19	1.	+ .01	11
.28	+ .20	.03	+0.37	−1.70	+1.14	−1.67	1.	+ .23	Nov. 28
.28	.15	.03	+0.03	1.71	1.12	1.69	1.	− .11	29
.28	+ .13	.02	−0.64	1.68	0.92	1.83	1.	− .77	Dec. 6
.28	− .05	.02	+0.25	1.66	0.82	1.87	1.	+ .12	9
.28	− .02	.02	+0.13	1.65	0.79	1.88	1.	+ .01	10
.28	+ .02	.02	+0.81	1.64	0.76	1.90	1.	+ .69	11
+ .29	+ .09	+0.02	+0.13	−1.59	+0.56	−1.97	1.	+ .02	17

C (2) 23 Hydrae. U Ophiuchi.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	′ ″	′ ″	′ ″	"
1891. Apr. 15	F.	+ 7.9	−0.03	−8 60.56	+3 17.70	−0 4.66	[12.45]
May 4	C.	+12.2	.03	50.86	16.92	15.60	10.43
14	C.	+35.2	.03	36.51	7.48	20.60	10.34
18	C.	+31.0	.03	34.38	8.19	22.49	11.29
23	C.	+23.0	.03	35.88	11.85	24.68	11.26
25	C.	+18.8	.03	37.53	13.73	25.52	10.65
26	C.	+21.6	.03	36.05	13.58	25.92	11.58 *a*
27	C.	+28.8	.03	34.40	10.37	26.32	9.63 *b*
28	C.	+33.0	.03	30.74	8.19	26.71	10.71
30	C.	+37.5	−0.03	−8 27.66	+3 6.43	+0 27.47	11.27

(*a*) A hurried observation.

(*b*) Large fires south of the observatory. Air filled with smoke rendering stars very faint and difficult to observe.

D=119° 54′ 13″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.03	0.00	....	....	....	....	....	0.	... .	1891. Apr. 15
.04	− .09	+1.35	+1.27	+0.76	−1.69	+1.00	1.	+0.19	May 4
.04	.48	1.28	1.82	1.01	1.45	1.27	1.	+ .73	14
.04	.35	1.27	0.75	1.10	1.40	1.38	1.	− .35	18
.04	.31	1.28	0.78	1.20	1.27	1.48	1.	− .89	23
.04	.28	1.28	1.31	1.25	1.20	1.52	1.	+ .19	25
.04	.27	1.28	0.87	1.27	1.17	1.54	1.	− .75	26
.04	.46	1.27	... .	....	....	....	0.	....	27
.04	.50	1.25	1.50	1.31	1.11	1.57	1.	+ .87	28
+0.04	−0.68	+1.24	+1.18	+1.34	−1.05	+1.60	0.5	.00	30

D (2) ι Hydrae. Ll. 32200.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1891. May 14	C.	+34.1	−0.02	−2 34.46	+3 8.42	−0 18.45	15.49
18	C.	+29.8	− .02	33.04	9.26	20.41	15.79
23	C.	+21.6	− .02	34.91	12.97	22.72	15.32
25	C.	+27.1	− .02	34.81	14.71	23.60	16.28
26	C.	+19.8	− .02	35.22	14.85	24.03	15.58
27	C.	+27.0	− .02	31.71	11.62	24.46	15.43
28	C.	+30.2	− .02	28.67	9.73	24.87	16.17
30	C.	+36.0	− .02	26.23	7.54	25.69	15.60
June 6	F.	+23.1	− .02	28.03	12.68	28.29	16.34
7	C.	+29.3	− .02	25.23	10.39	28.64	16.50
8	F.	+33.1	− .02	−2 22.55	+3 8.61	−0 28.97	17.07

D = 120° 0′ 16″.00

μ	r	$\varphi\ (d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.10	−0.38	+0.11	+0.68	+0.90	−1.48	+1.28	1.	+0.45	1891. May 14
.10	.27	.11	+0.27	1.00	1.40	1.38	1.	+ .03	18
.10	.23	.11	+0.70	1.11	1.27	1.48	1.	+ .45	23
.10	.34	.11	−0.15	1.15	1.20	1.51	1.	− .40	25
.10	.24	.12	+0.44	1.17	1.17	1.53	1.	+ .19	26
.10	.35	.11	+0.71	1.19	1.14	1.55	1.	+ .46	27
.10	.39	.11	+0.01	1.21	1.11	1.57	1.	− .26	28
.10	.55	.10	+0.75	1.25	1.05	1.60	1.	+ .48	30
.11	.26	....	−0.19	1.39	0.84	1.70	0.5	− .47	June 6
.11	.35	+0.10	−0.36	1.40	0.81	1.71	1.	− .65	7
+0.11	−0.46	....	−0.72	+1.42	−0.78	+1.72	0.5	−1.01	8

E (2). *p*[3] Leonis. *g* Aquilae.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	' "	' "	' "	"
1891. May 18	C.	+27.0	−0.03	−3 60.55	+3 9.75	−0 8.75	0.43
30	C.	+33.4	− .03	51.83	8.00	15.29	0.85
June 7	C.	+26.2	− .03	50.94	11.09	19.33	0.79
8	F.	+31.1	− .03	47.19	8.90	19.80	1.88
9	C.	+41.0	− .03	43.32	4.83	20.26	1 22
11	C.	+36.3	− .03	44.94	7.67	21.19	1.51
12	F.	+35.7	− .03	45.40	7.93	21.65	0.85
13	C.	+42.3	− .03	41.39	5.08	22.10	1.56
15	C.	+46.4	− .03	39.02	3.52	22.98	1.49
20	F.	+39.4	− .03	36.40	4.74	25.06	[3.25]
23	F.	+41.7	− .03	37.39	5.33	25.86	2.05
23	F.	+42.8	− .03	37.74	5.23	26.24	1.22
24	F.	+46.2	−0.03	−3 35.76	+3 4.48	−0 26.62	2.07

D = 119° 59′ 1″ 50

μ	r	$\varphi (d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.02	−0.25	+0.28	+1.07	+0.43	−1.40	+1.38	1.	+0.46	1891. May 18
.02	.55	.26	+0.96	0.75	1.05	1.60	1.	+ .33	30
.02	.32	.26	+0.79	0.95	0.81	1.71	1.	+ .14	June 7
.02	.45	....	+0.09	0.97	0.78	1.72	0.5	− .56	8
.02	.70	.24	+0.76	0.99	0.75	1.73	1.	+ .11	9
.02	.48	.24	+0.25	1.05	0.69	1.75	1.	− .40	11
.03	.47	....	+1.15	1.06	0.66	1.76	0.5	+ .50	12
.03	.70	.23	+0.44	1.08	0.63	1.77	1.	− .22	13
.03	.85	+0.23	+0.66	1.12	0.57	1.78	1.	.00	15
.03	.76	....	....	....	....	....	0.	....	20
.03	.70	....	+0.18	1.26	0.36	1.82	0.5	− .50	22
.03	.70	....	+1.01	1.28	0.33	1.82	0.5	+ .33	23
−0.03	−0.77	....	+0.23	+1.30	−0.30	+1.83	0.5	− .45	24

F (2) υ Leonis. ι Aquilae.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1891. May 18	C.	+26.2	−0.03	−8 30.55	+3 9.96	−0 4.18	35.20
28	C.	+25.6	.03	26.51	10.87	9.72	34.61
30	C.	+32.7	.03	22.42	8.28	10.80	35.03
June 7	C.	+24.8	.03	21.28	11.62	14.99	35.32
8	F.	+30.8	.03	17.16	9.04	15.49	36.36
9	C.	+39.8	.03	14.18	5.27	15.98	35.08
11	C.	+36.8	.03	15.12	7.56	16.97	35.44
12	F.	+34.6	.03	16.14	8.34	17.45	34.72
13	C.	+41.1	.03	12.01	5.54	17.93	35.57
15	C.	+45.3	.03	10.18	3.94	18.88	34.85
22	F.	+41.0	.03	6.99	5.63	22.01	36.60
23	F.	+41.4	.03	6.58	5.71	22.44	36.66
July 1	F.	+31.6	−0.03	−8 7.02	+3 8.60	−0 25.61	35.94

D = 119° 54′ 37″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.01	−0.27	+1.30	+0.76	+0.21	−1.40	+1.38	1.	−0.42	1891. May 18
.01	− .39	1.28	+1.49	0.48	1.11	1.57	1.	+ 29	28
.01	− .61	1.26	+1.31	0.53	1.05	1.60	1.	+ .11	30
.01	− .34	1.25	+0.76	0.73	0.81	1.71	1.	− .46	June 7
.01	− .44	....	+1.07	0.75	0.78	1.72	0.5	− .15	8
.01	− .79	1.18	+1.52	0.78	0.75	1.73	1.	+ .30	9
.01	− .58	1.18	+0.95	0.83	0.69	1.75	1.	− .27	11
.01	− .56	....	....	....	....	....	0.0	....	12
.01	− .79	1.17	+1.04	0.88	0.63	1.76	1.	− .19	13
.01	− .97	+1.16	+1.95	0.92	0.57	1.78	1.	+ .72	15
.02	− .74	....	+1.12	1.08	0.36	1.81	0.5	− .12	22
.02	− .76	....	+1.08	1.10	0.33	1.81	0.5	− .16	23
+0.02	−0.45	....	+1.49	+1.25	−0.09	+1.84	0.5	+ .22	July 1

Δ (3) B. D. + 2°, 2664. 16 Aquarii.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1891. Apr. 7	C.	− 7.7	−0.03	−9 23.17	+3 23.59	+0 28.62	29.01
11	C.	+ 1.1	− .03	17.74	19.78	27.41	29.42
18	F.	+13.1	− .03	11.02	15.44	24.97	29.36
21	C.	+27.2	− .03	4.58	9.03	23.86	(*a*) 28.28
22	F.	+19.0	− .03	4.44	11.68	23.47	30.68
23	C.	+ 7.4	− .03	10.14	16.39	23.07	29.29
24	F.	+19.1	− .03	5.15	12.55	22.67	30.04
25	C.	+20.0	− .03	5.61	12.98	22.26	29.60
28	F.	+16.8	− .03	5.94	14.06	20.99	29.08
May 2	F.	+ 5.2	− .03	5.90	17.86	19.20	31.13
5	C.	+ 8.9	− .03	7.02	18.76	17.81	29.52
6	F.	+16.7	− .03	−9 3.88	15.63	+0 17.34	29.06
June 22	F.	+38.8	−0.03	−8 27.18	+3 6.27	−0 7.68	31.38

(*a*) A hurried and incomplete observation.

D = 119° 54′ 31″.00

μ	r	$\varphi\,(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.04	+0.18	+1.53	+0.32	−1.40	−1.99	+0.18	1.	−0.04	1891. Apr. 7
.04	+ .10	1.44	+0.03	1.34	1.96	0.31	1.	− .33	11
.04	− .12	....	....	....	....	....	0.0	....	18
.04	− .51	1.43	+1.34	1.16	1.87	0.63	0.5	+1.47	21
.04	− .26	....	+0.62	1.14	1.86	0.66	0.5	+ .24	22
.04	.00	1.46	+0.29	1.12	1.85	0.69	1.	− .09	23
.04	− .26	....	+1.26	1.10	1.84	0.72	0.5	+ .88	24
.04	− .32	1.44	+0.22	1.09	1.82	0.75	1.	− .16	25
.04	− .15	....	....	....	....	....	0.0	....	28
.04	+ .07	....	−0.16	0.94	1.71	0.94	0.5	− .55	May 2
.04	+ .01	+1.45	+0.03	0.87	1.67	1.03	1.	− .37	5
.04	− .12	....	....	....	....	....	0.0	....	6
−0.04	− .34	....	+0.50	+0.37	−0.35	+1.31	0.5	+ .02	June 22

X. μ Virginis. ς Pegasi.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	' "	' "	' "	"
1891. Apr. 4	F.	−10.2	−0.02	+1 12.03	+3 25.58	+0 31.07	8.66
7	C.	− 7.8	− .02	14.02	24.84	30.87	9.71
11	C.	+ 0.9	− .02	18.86	20.94	30.48	10.26
18	F.	+13.0	− .02	22.85	16.62	29.44	8.89
21	C.	+27.0	− .02	31.11	10.14	28.89	10.12
22	F.	+19.0	− .02	28.81	12.74	28.69	10.22
23	C.	+ 6.7	− .02	23.68	17.72	28.48	9.86
25	C.	+19.5	− .02	27.70	14.27	28.02	9.97
28	F.	+16.9	− .02	27.96	15.06	27.30	10.30
May 2	F.	+ 3.9	− .02	23.08	19.50	26.21	8.77
4	F.	+ 1.5	− .02	20.83	22.82	25.62	9.25
5	C.	+ 8.8	− .02	25.33	19.93	25.32	10.56
6	F.	+15.7	− .02	27.64	17.10	25.00	9.72
7	C.	+21.0	− .02	30.64	14.04	24.68	9.34
8	F.	+26.5	− .02	34.35	10.79	24.36	9.48
10	F.	+ 6.8	− .02	26.22	19.13	23.69	9.02
11	C.	+16.3	− .02	31.06	15.75	23.35	10.14
12	F.	+22.7	− .02	32.96	13.05	22.99	8.98
13	C.	+15.5	− .02	31.85	16.19	22.63	10.65
16	F.	+ 3.7	− .02	1 27.69	21.34	+ 21.53	10.54
Aug. 11	C.	+38.7	− .02	2 21.67	7.67	− 19.81	9.51
12	C.	+38.0	− .02	+2 21.45	8.49	−0 20.21	9.71

$D = 120° \; 5' \; 10''.00$

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
"	"	"	"					"	
+0.04	−0.03	... .	....	....	....	....	0.0	....	1891. Apr. 4
.04	.04	−0.02	+0.31	−1.51	−1.99	+0.18	1.	+0.19	7
.04	.09	.03	−0.18	1.49	1.96	0.31	1.	− .30	11
.04	.19	....	....	....	... .	....	0.0	....	18
.04	.42	.04	+0.30	1.41	1.87	0.63	1.	+ .17	21
.04	.23	....	−0.03	1.40	1.86	0.66	0.5	− .16	22
.04	.11	.03	+0.24	1.39	1.84	0.69	1.	+ .11	23
.04	.19	.04	+0.22	1.37	1.82	0.75	1.	+ .09	25
.04	.19	....	−0.15	1.34	1.78	0.83	0.5	− .29	28
.04	.09	....	....	....	....	....	0.0	....	May 2
.04	.10	....	+0.81	1.25	1.69	1.00	0.5	+ .67	4
.04	.10	.04	−0.46	1.24	1.66	1.03	1.	− .61	5
.04	.14	....	+0.38	1.22	1.64	1.06	0.5	+ .28	6
.04	.20	.04	+0.86	1.20	1.63	1.09	1.	+ .71	7
.04	.24	....	+0.72	1.19	1.61	1.11	0.5	+ .57	8
.04	.11	....	+1.05	1.15	1.57	1.17	0.5	+ .90	10
.04	.17	.04	+0.03	1.14	1.55	1.20	1.	− .12	11
.04	.20	....	....	... .	....	....	0.0	....	12
.04	.16	.04	−0.49	1.10	1.51	1.25	1.	− .64	13
.04	.07	... .	−0.51	−1.06	−1.44	1.32	0.5	− .67	16
.05	.44	.09	+0.97	+0.97	+1.12	1.49	1.	+ .65	Aug. 11
+0.05	−0.41	−0.09	+0.74	+0.99	+1.15	1.47	1.	+ .42	12

X. μ Virginis. ς Pegasi. — Continued.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1891. Aug. 13	C.	+35.5	−0.02	+2 22.16	+3 8.69	−0 20.60	10.23
15	C	+43.8	− .02	25.81	5.95	21.37	10.37
28	C.	+30.6	− .02	25.36	10.37	25.79	9.92
Sept. 4	C.	+27.7	− .02	25.61	12.22	27.69	10.12
6	C.	+38.6	− .02	29.90	8.76	28.16	10.48
8	C.	+38.3	− .02	29.68	9.26	28.60	10.32
10	C.	+39.5	− .02	30.41	8.23	29.01	9.61
12	C.	+40.4	− .02	32.84	6.84	29.38	10.28
13	C.	+36.5	−0.02	+2 31.04	+3 8.92	−0 29.56	10.38

XI. φ Virginis. ς Aquarii.

		div.	″	′ ″	′ ″	′ ″	″
1891. Apr. 23	C.	+ 6.3	−0.03	+3 29.10	+3 17.78	+0 29.27	16.12
24	F.	+18.3	− .03	+3 36.32	+3 13.75	+0 29.01	19.05

D = 120° 5′ 10″.00.

μ	τ	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.05	−0.33	−0.09	+0.14	+1.01	+1.18	+1.44	1.	−0.18	1891. Aug. 13
.05	.56	.10	+0.24	1.05	1.24	1.39	1.	− .09	15
.05	.23	.10	+0 36	1.26	1.53	1.08	1.	+ .01	28
.05	.35	.10	+0.28	1.35	1.65	0.89	1.	− .08	Sept. 4
.05	.48	.11	+0.06	1.38	1.67	0 84	1.	− .30	6
.05	.48	.11	+0.22	1.40	1.70	0.78	1.	− .14	8
.05	.43	.11	+0.88	1.42	1.73	0.72	1.	+ .52	10
.05	.40	.11	+0.18	1.44	1.75	0 66	1.	- .18	12
+0.05	−0.40	−0.11	+0.08	+1.45	+1.77	+0.63	1.	−0.28	18

D = 120° 7′ 16″.00.

″	″	″	″					″	
−0.46	−0.14	−0.21	+0.69	−1.43	−1.84	+0.69	1.	....	91. Apr. 23
− .46	− .26	....	....	....	....	....	0.0	....	24

XII. 37 Librae. 70 Pegasi.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Sep. 21	F.	+30.0	+0.47	−0 43.48	+3 10.32	−0 29.73	57.58
21	C.	+30.0	+ .23	−0 42.86	10.32	− 29.73	57.96
1891. May 7	C.	+20.1	− .02	−1 44.80	13.96	+ 29.63	58.77
11	C.	+16.3	.02	44.21	15.36	28.66	59.79
13	C.	+15.0	.02	45.78	16.01	28.13	58.34
16	F.	+ 3.5	.02	47.50	21.04	27.27	(*a*) 60.79
17	C.	+18.3	.02	41.92	14.13	26.96	59.15
18	F.	+22.1	.02	39.52	11.99	26.66	59.11
20	F.	+33.0	.02	36.54	8.61	26.01	58.06
22	F.	+12.2	.02	43.75	17.04	25.34	58.61
23	C.	+16.3	.02	40.84	14.80	25.00	58.94
25	C.	+10.7	.02	−1 43.64	17.74	+ 24.30	58.38
Aug. 28	C.	+29.2	.02	−0 50.27	10.43	− 21.94	58.20
Sep. 4	C.	+26.4	.02	49.22	12.38	24.63	58.51
8	C.	+38.0	.02	44.44	9.01	26.01	58.54
10	C.	+37.5	.02	43.90	8.53	26.66	57.95
12	C.	+38.8	.02	41.24	7.10	27.28	58.56
13	C.	+35.5	.02	43.29	8.87	27.57	57.99
14	C.	+48.0	.02	36.74	3.07	27.86	58.45
15	C.	+44.5	.02	38.26	5.42	28.14	59.00
23	C.	+52.0	−0.02	−0 33.65	+3 2.64	−0 30.10	58.87

(*a*) Observer notes: "Don't know about angles. Found reel on *I* when I supposed it was on *III*. Reject. Same angle probably used twice."

D = 120° 1′ 59″.00.

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.15	−0.40	....	....	....	....	....	0.	....	1890. Sept. 21
.15	.40	+0.01	+1.28	+1.46	+1.85	+0.87	1.	+0.72	21
.28	.32	.05	+0.12	−1.43	−1.63	1.09	1.	− .23	1891. May 7
.28	.16	.05	−0.96	1.40	1.55	1.20	0.5	−1.31	11
.28	.14	.06	+0.46	1.38	1.51	1.25	1.	+ .11	13
.28	.01	....	....	....	....	....	0.	....	16
.28	.17	.05	−0.32	1.32	1.41	1.36	1.	− .68	17
.28	.26	....	−0.13	1.30	1.39	1.37	0.5	− .49	18
.29	.29	....	+0.94	1.27	1.35	1.42	0.25	+ .58	20
.29	.16	....	+0.26	1.24	1.29	1.46	0.5	− .10	22
.29	.21	.05	−0.07	1.22	1.26	1.48	1.	− .44	23
.29	.23	.05	+0.50	−1.19	−1.20	1.52	1.	+ .12	25
.34	.27	.01	+0.72	+1.08	+1.53	1.08	1.	+ .18	Aug. 28
.34	.36	.01	+0.50	1.20	1.65	0.89	1.	− .05	Sept. 4
.34	.52	.01	+0.63	1.27	1.70	0.78	1.	+ .08	8
.35	.48	.01	+1.17	1.30	1.73	0.71	1.	+ .61	10
.35	.46	.01	+0.54	1.33	1.75	0.66	1.	− .02	12
.35	.45	.01	+1.10	1.35	1.77	0.63	1.	+ .54	13
.35	.61	.01	+0.80	1.36	1.78	0.60	1.	+ .24	14
.35	.64	.01	+0.28	1.38	1.79	0.56	1.	− .28	15
+0.35	−0.70	+0.00	+0.48	+1.47	+1.87	+0.80	1.	−0.08	28

XIII. β Librae. γ Piscium.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ "	′ "	′ "	"
1890. Sep. 27	F.	+19.5	+0.49	+5 20.78	+8 15.93	−0 33.08	4.17
28	C.	+25.9	+ .35	24.86	18.26	33.17	5.30
29	F.	+32.4	+ .35	5 24.96	10.60	− 33.30	2.61
1891. Apr. 18	F.	+12.3	− .03	4 15.39	16.36	+ 33.54	5.26
22	F.	+19.0	.03	20.24	12.22	33.07	5.50
23	C.	+ 6.1	.03	15.58	17.48	32.92	5.95
24	F.	+18.9	.03	20.43	13.19	32.77	6.36
25	C.	+18.3	.03	19.89	14.12	32.61	6.59
28	F.	+17.0	.03	20.37	14.46	32.07	6.87
May 2	F.	+ 2.7	.03	13.17	19.53	31.22	3.89
4	F.	+ 0.7	.03	10.91	23.11	30.74	4.73
5	C.	+ 7.5	.03	16.08	19.91	30.49	6.45
6	F.	+14.4	.03	18.01	17.01	30.23	5.22
8	F.	+26.1	.03	25.68	10.31	29.68	5.64
10	F.	+ 6.4	.03	4 17.36	18.73	+ 29.10	5.16
Aug. 28	C.	+28.4	.03	5 20.83	10.53	− 24.67	6.66
31	C.	+31.6	−0.03	+5 22.59	+8 10.37	−0 25.83	7.10

D=120° 8′ 5″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.46	−0.26	....	....	....	....	....	0.	....	1890. Sept. 27
.46	− .26	−0.50	+0.92	+1.62	+1.89	+0.13	1.	+0 58	28
.46	− .29	....	....	....	....	....	0.	....	29
.80	− .21	....	+0.75	−1.64	−1.90	0.54	0.25	+ .64	1891. Apr. 18
.81	− .25	....	+0.56	1.61	1.86	0.66	0.5	+ .45	22
.81	− .15	.32	+0.38	1.61	1.84	0.69	1.	+ .22	23
.81	− .25	....	−0.30	1.60	1.83	0.72	0.25	− .41	24
.81	− .21	.33	−0.24	1.59	1.82	0.75	1.	− .35	25
.82	− .21	....	−0.84	1.56	1.78	0.83	0.5	− .96	28
.82	− .18	....	....	....	....	....	0.	....	May 2
.83	− .12	....	....	....	....	....	0.	....	4
.83	− .12	.32	−0.18	1.49	1.67	1.03	1.	− .31	5
.83	− .17	....	+0.78	1.48	1.65	1.06	0.5	+ .65	6
.84	− .23	....	+0.43	1.45	1.61	1.12	0.5	+ .30	8
.84	− .12	....	+0.80	−1.42	−1.57	1.17	0.5	+ .67	10
1.02	− .20	.49	+0.05	+1.20	+1.53	1.08	1.	− .28	Aug. 28
−1.03	−0.40	−0.50	−0.17	+1.26	+1.58	+1.03	1.	−0.50	31

B (8). 110 Virginis. β Piscium.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1891. May 7	C.	+19.1	−0.02	−4 36.37	+8 14.38	+0 26.67	4.66
11	C.	16.3	− .02	35.76	15.40	25.53	5.15
12	F.	22.9	− .02	33.52	13.64	25.23	4.33
13	C.	14.5	− .02	37.67	16.25	24.91	(*a*) 3.47
14	F.	31.0	− .02	29.81	9.63	24.60	4.40
16	F.	3.3	− .02	39.72	21.20	23.94	5.40
17	C.	18.3	− .02	33.25	14.12	23.60	4.45
18	F.	21.8	− .02	30.97	12.17	23.26	4.44
22	F.	11.8	− .02	33.97	17.26	21.82	5.09
23	C.	15.7	− .02	4 32.38	15.06	+ 21.45	4.11
Aug. 31	C.	31.0	− .02	3 40.61	10.79	− 24.54	5.62
Sept. 3	C.	28.5	− .02	41.37	11.44	25.47	4.58
4	C.	25.8	− .02	41.46	12.68	25.77	5.43
8	C.	37.4	− .02	37.83	9.27	26.90	4.52
9	C.	34.2	− .02	37.61	10.43	27.16	5.64
12	C.	37.5	− .02	34.71	7.66	27.90	5.03
13	C.	34.6	− .02	36.09	9.22	28.13	4.98
14	C.	47.7	− .02	30.55	3.24	28.35	4.32
15	C.	43.6	− .02	32.35	5.78	28.57	4.84
17	C.	55.3	− .02	28.16	2.21	28.97	5.06
20	C.	55.4	− .02	26.86	1.91	29.52	5.51
22	C.	52.8	− .02	28.25	3.22	29.84	5.11
29	C.	+27.3	−0.02	−3 35.64	+8 12.06	−0 30.70	5.70

(*a*) Observer notes: "My personal equation is abnormal this morning. Two or three times I have caught myself in the act of writing down a wrong figure."

$D = 119° \; 59' \; 5''.00$

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.09	−0.19	+0.37	+0.25	−1.30	−1.63	+1.09	1.	+0.04	1891. May 7
.09	− .05	.37	−0.38	1.25	1.55	1.20	1.	− .59	11
.09	− .28	....	+1.04	1.28	1.53	1.22	0.25	+ .83	12
.09	− .13	.37	+1.38	1.22	1.51	1.24	0.25	+1.17	13
.10	− 85	....	+0.85	1.20	1.49	1.27	1.	+ .64	14
.10	+ .03	....	−0.33	1.17	1.45	1.32	1.	− .56	16
.10	− .08	.36	+0.37	1.15	1.42	1.36	1.	+ .14	17
.10	− .24	....	+0.90	1.13	1.40	1.38	0.25	+ .66	18
.10	− .11	....	+0.13	1.07	1.30	1.46	1.	− .11	22
.10	− .19	.36	+0.82	−1.05	−1.28	1.48	1.	+ .59	23
.12	− .51	.23	−0.22	+1.20	+1.58	1.00	1.	− .63	Aug. 31
.12	− .30	.23	+0.61	1.24	1.63	0.92	1.	+ .20	Sept. 3
.12	− .38	.23	−0.16	1.26	1.65	0.89	1.	− .58	4
.12	− .55	.23	+0.92	1.32	1.70	0.78	1.	+ .50	8
.12	− .44	.23	−0.31	1.33	1.72	0.75	1.	− .73	9
.12	− .50	.22	+0.37	1.37	1.75	0.66	1.	− .05	12
.12	− .49	.22	+0.41	1.38	1.77	0.62	1.	− .01	13
.12	− .69	.21	+1.28	1.39	1.78	0.59	0.5	+ .86	14
.12	− .70	.21	+0.77	1.40	1.79	0.56	1.	+ .35	15
.12	− .91	.20	+0.77	1.42	1.81	0.50	1.	+ .35	17
.12	− .89	.20	+0.30	1.45	1.84	0.40	1.	− .12	20
.12	− .79	.20	+0.60	1.46	1.85	0.33	1.	+ .18	22
−0.12	−0.88	+0.22	−0.42	+1.50	+1.90	+0.09	1.	− .84	29

XIV. 8 Serpentis. φ Aquarii.

Date.	Obs'r.	Temp.	K	d	R	A	$\varDelta$
		div.	"	' "	' "	' "	"
1890. Sep. 21	F.	+27.0	+0.35	+1 54.13	+3 11.47	−0 31.18	34.77
22	C.	+36.7	.35	57.09	11.36	31.36	37.44
23	F.	+29.0	.35	56.12	11.29	31.54	36.22
27	F.	+18.2	.35	52.57	16.62	32.14	37.40
28	C.	+24.8	.35	55.81	13.87	32.26	37.77
29	F.	+31.9	.35	57.59	11.00	32.39	36.55
Oct. 14	C.	+19.8	.22	58.18	11.53	33.02	36.91
17	F.	+22.5	.35	56.81	11.93	32.89	36.20
20	C.	+16.9	+ .22	1 54.89	15.03	− 32.65	37.49
1891. May 5	C.	+ 6.0	− .02	0 47.35	20.65	+ 29.44	37.42
7	C.	+17.8	.02	53.32	14.79	28.91	37.00
11	C.	+16.7	.02	54.60	15.36	27.77	37.71
13	C.	+14.0	.02	54.19	16.41	27.14	37.72
16	F.	+ 3.1	.02	49.49	21.23	26.16	36.86
17	C.	+18.4	.02	57.25	14.06	25.81	37.10
18	F.	+20.9	.02	59.27	12.42	25.47	37.14
22	F.	+11.2	.02	55.63	17.46	23.99	37.06
23	C.	+15.0	.02	58.55	15.29	23.62	37.44
25	C.	+ 9.4	.02	0 56.10	18.31	22.84	37.23
27	C.	+21.3	.02	1 2.05	13.71	22.02	37.76
28	F.	+18.3	.02	2.42	13.97	21.60	37.97
29	C.	+23.1	.02	4.19	12.16	21.18	37.51
31	C.	+33.9	.02	10.28	7.26	20.33	37.85
June 7	C.	+19.4	.02	6.01	14.08	17.15	37.22
9	F.	+36.4	.02	14.69	6.88	16.20	37.75
11	F.	+29.9	.02	10.47	10.73	15.23	36.41
13	F.	+36.7	.02	17.03	7.38	+ 14.24	38.63
Aug. 28	C.	+27.1	.02	51.01	11.12	− 24.18	37.93
31	C.	+29.2	−0.02	+1 51.91	+3 11.41	−0 25.29	38.01

D = 120° 4′ 37″.50

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.04	−0.36	....	....	......	....	....	0.	......	1890. Sept. 21
.04	.36	−0.07	+0.53	+1.54	+1.86	+0.33	1.	+0.06	22
.04	.40	....	....	....	....	....	0.	....	23
.04	.28	....	+0.42	1.57	1.80	0.16	0.5	− .05	27
.04	.27	.07	+0.11	1.57	1.89	0.13	1.	− .36	28
.04	.39	....	+1.38	1.58	1.90	+0.09	0.5	+ .91	29
.04	.22	.07	+0.92	1.61	1.90	−0.40	0.5	+ .46	Oct. 14
.04	.27	....	....	....	....	....	0.	....	17
.04	.21	.06	+0.32	+1.59	+1.85	−0.60	1.	− .14	20
.08	.09	.01	+0.26	−1.44	−1.67	+1.03	0.5	+ .01	1891. May 5
.08	.19	.01	+0.78	1.42	1.63	1.09	0.5	+ .52	7
.08	.17	.01	+0.05	1.35	1.55	1.20	1.	− .21	11
.08	.16	.01	+0.03	1.33	1.51	1.25	0.5	− .23	13
.08	.07	....	+0.79	1.28	1.45	1.34	0.25	+ .52	16
.08	.17	.02	+0.67	1.26	1.42	1.36	1.	+ .40	17
.08	.18	....	+0.62	1.24	1.40	1.38	0.5	+ .35	18
.08	.18	....	+0.70	1.17	1.30	1.46	0.5	+ .48	22
.08	.21	.02	+0.37	1.15	1.27	1.48	1.	+ .09	23
.08	.16	.02	+0.53	1.11	1.20	1.52	1.	+ .25	25
.08	.30	.02	+0.14	1.08	1.14	1.55	0.5	− .14	27
.08	.29	....	−0.10	1.06	1.11	1.57	0.5	− .39	28
.08	.31	.02	+0 40	1.04	1.08	1.58	1.	+ .11	29
.08	.53	.02	+0.28	1.00	1.02	1.61	0.5	− .01	31
.08	.22	.02	+0.60	0.84	0.81	1 71	1.	+ .28	June 7
.08	.54	....	+0.37	0.79	0.75	1.73	0.5	+ .05	9
.08	.34	....	+1.51	0.74	0.72	1.75	0.5	+1.18	11
.08	.38	....	−0.67	−0.69	−0.63	1.77	0.5	−1.00	13
.10	.23	.06	−0.04	+1.18	+1.53	1.08	1.	− .49	Aug. 28
−0.10	−0.44	−0.06	+0.09	+1.23	+1.58	+1.00	1.	−0.37	31

8 Serpentis. φ Aquarii — Continued.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1891. Sept 3	C.	+26.9	−0.02	+1 51.80	+3 12.06	+0 26.34	37.50
4	C.	+25.0	.02	51.52	12.98	26.67	37.81
5	C.	+32.8	.02	54.19	10.33	27.00	37.50
8	C.	+35.4	.02	54.82	10.52	27.94	37.38
9	C.	+35.2	.02	56.02	10.03	28.23	37.80
12	C.	+36 3	.02	58.32	8.05	29.07	37.28
13	C.	+33.4	.02	57.26	9.63	29.33	37.54
15	C.	+40.8	.02	60.38	6.72	29.83	37.25
17	C.	+54.2	.02	66.09	2.53	30.30	38.30
20	C.	+53.6	.02	66.63	2.49	30.93	38.17
22	C.	+50.9	.02	64.99	3.84	31.31	37.50
23	C.	+49.1	.02	65.11	3.55	31.49	37.15
29	C.	+25.6	.02	57.35	12.63	32.36	37.60
Oct. 5	C.	+16.7	.02	56.19	15.13	32.89	(*a*) 38.41
7	C.	+19.6	.02	56.46	13.87	32.98	37.33
10	C.	+28.0	.02	59.35	11.57	33.06	37.84
11	C.	+17.6	−0.02	+1 54.74	+3 16.68	+0 33.07	38.33

(*a*) Incomplete observation. Micrometer coincidence not eliminated.

XVIII. B. A. C. 5647. 17 Ceti.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1891. July 5	C.	+30.0	−0.03	+0 21.94	+3 10.08	+0 16.66	48.65
9	C.	+24.6	− .03	+0 20.48	+3 13.03	+0 14.71	48.19

D = 120° 4′ 37″.50.

μ	τ	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.10	−0.24	−0.06	+0.40	+1.29	+1.63	+0.93	1.	−0.07	1891. Sept. 3
.10	.34	.06	+0.19	1.30	1.64	0.89	1.	− .28	4
.10	.38	.06	+0.54	1.32	1.66	0.87	1.	+ .07	5
.10	.45	.06	+0.73	1.37	1.70	0.78	1.	+ .26	8
.10	.37	.07	+0.24	1.38	1.74	0.75	1.	− .23	9
.10	.40	.07	+0.75	1.42	1.75	0.66	1.	+ .28	12
.10	.40	.07	+0.53	1.44	1.77	0.62	1.	+ .06	13
.10	.57	.07	+0.99	1.46	1.79	0.56	1.	+ .52	15
.10	.73	.08	+0.11	1.48	1.81	0.50	1.	− .36	17
.10	.70	.08	+0.21	1.52	1.84	0.40	1.	− .26	20
.10	.60	.07	+0.77	1.54	1.85	0.33	1.	+ .30	22
.10	.62	.08	+1.15	1.54	1.87	0.29	1.	+ .68	23
.10	.32	.07	+0.39	1.58	1.90	+0.09	1.	+ .12	29
.10	.18	.07	−0.56	1.60	1.92	−0.11	0.5	−1.03	Oct 5
.10	.28	.07	+0.62	1.61	1.92	0.18	1.	+ .15	7
.10	.34	.07	+0.17	1.61	1.91	0.28	1.	− .30	10
−0.10	−0.22	−0.06	−0.45	+1.61	+1.91	−0.30	1.	−0.92	11

D = 120° 3′ 48″.00.

μ	τ	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.03	−0.38	0.00	−0.24	−0.81	+0.01	+1.84	1.	−0.20	1891 July 5
−0.03	− .31	.00	+0.15	−0.71	+0.16	+1.84	1.	+0.18	9

.XV δ Ophiuchi. ι Ceti.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ "	′ "	′ "	"
1890. Sep. 21	F.	+25.3	+0.34	+5 12.39	+8 11.06	−0 39.66	54.03
22	C	+25.5	+ .34	13.52	10.74	29.97	54.63
27	F.	+16.6	+ .34	8.45	16.25	31.44	53.60
28	C.	+23.6	+ .34	13.31	13.29	31.70	55.24
29	F.	+28.2	+ .34	14.57	11.27	31.96	54.22
30	C.	+27.5	+ .34	16.12	10.73	32.20	54.99
Oct. 13	C.	+17.0	+ .50	18.78	9.97	34.53	54.73
14	C.	+16.2	+ .18	18.14	11.39	34.65	55.56
17	F.	+21.3	+ .34	17.49	11.34	34.91	54.26
18	C.	+13.4	+ .34	14.42	14.24	34.97	54.03
20	C.	+16.4	+ .34	15.74	14.24	35.09	55.23
22	C.	+18.6	+ .34	17.29	12.82	35.15	55.30
23	F.	+18.0	+ .34	16.52	12.47	35.17	54.16
26	C.	+ 6.6	+ .34	10.63	18.20	35.15	54.02
Nov. 4	C.	+ 4.0	+ .34	5 11.72	17.10	− 34.52	54.64
1891. May 17	C.	+18.5	− .03	4 8.95	13.05	+ 31.71	53.68
22	F.	+10.9	− .03	8.00	16.59	30.34	54.90
23	C.	+14.4	− .03	9.40	14.51	30.04	53.92
25	C.	+ 8.8	− .03	7.54	17.52	29.42	54.45
27	C.	+20.2	− .03	12.72	13.07	28.75	54.51
28	F.	+20.2	− .03	15.02	12.88	28.41	55.73
29	C.	+22.5	− .03	14.63	11.39	28.05	54.04
June 4	C.	+14.8	− .03	12.14	15.69	25.79	53.59
7	F.	+18.8	− .03	15.63	13.26	24.56	53.42
9	F.	+35.5	− .03	25.00	6.13	23.72	54.82
10	C.	+29.0	−0.03	+4 22.56	+3 9.05	+0 23.28	54.86

D = 120° 7′ 54″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.01	−0.34	....	+0.30	+1.45	+1.84	+0.37	0.5	+0.38	1890. Sept. 21
.01	.34	−0.47	+0.17	1.47	1.85	0.33	1.	+ .20	22
.01	.25	....	....	....	....	....	0.	....	27
.01	.26	.47	−0.52	1.55	1.89	0.13	1.	− .49	28
.01	.28	....	+0.05	1.56	1.90	0.10	0.5	+ .08	29
.01	.26	.48	−0.26	1.57	1.90	+0.06	1.	− .23	30
.01	.22	.48	−0.03	1.69	1.90	−0.38	0.5	+ .01	Oct. 13
.01	.22	.48	−0.87	1.69	1.90	0.40	0.5	− .83	14
.01	.23	....	−0.04	1.71	1.88	0.50	0.5	.00	17
.01	.22	.47	+0.65	1.71	1.87	0.53	1.	+ .69	18
.01	.22	.48	−0.54	1.71	1.85	0.60	1.	− .50	20
.01	.23	.48	−0.60	1.72	1.83	0.66	1.	− .56	22
.01	.23	....	+0.06	1.72	1.82	0.70	0.5	+ .10	23
.01	.18	.46	+0.56	1.72	1.79	0.79	1.	+ .60	26
.01	.18	.46	−0.06	+1.69	+1.68	−1.07	1.	− .01	Nov. 4
.02	.18	.30	+0.78	−1.55	−1.42	+1.36	0.5	+1.01	1891. May 17
.02	.19	....	−0.73	1.49	1.29	1.46	0.5	− .50	22
.02	.23	.30	+0.59	1.47	1.26	1.48	1.	+ .82	23
.02	.19	.30	+0.02	1.44	1.20	1.52	0.5	+ .24	25
.02	.29	.31	+0.07	1.41	1.14	1.55	1.	+ .29	27
.02	.29	....	....	....	....	....	0.	....	28
.02	.30	.31	+0.55	1.37	1.08	1.58	1.	+ .76	29
.02	.31	.31	+0.91	1.25	0.90	1.67	1.	+1.11	June 4
.02	.33	....	+0.79	1.20	0.81	1.71	0.5	+ .99	7
.02	.34	....	−0.50	1.15	0.75	1.73	0.5	− .31	9
+0.02	−0.34	−0.34	−0.20	−1.18	−0.72	+1.74	1.	−0.01	10

δ Ophiuchi. ι Ceti. — Continued.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	″	′ ″	′ ″	′ ″	″
1891. June 11	F.	+27.9	−0.03	+4 18.95	+3 10.44	+0 22.83	52.19
13	F.	36.5	− .03	27.09	6.45	21.93	55.44
15	F.	41.2	− .03	4 29.89	4.65	+ 21.01	55.52
Sept. 3	C.	24.3	− .03	5 4.75	11.99	− 22.48	54.23
8	C.	30.8	− .03	9.15	10.48	24.68	54.92
9	C.	35.0	− .03	10.30	9.11	25.11	54.27
12	C.	35.6	− .03	14.09	7.32	26.82	55.06
13	C.	30.0	− .03	12.16	9.79	26.71	55.21
15	C.	37.3	− .03	15.40	6.90	27.47	54.80
17	C.	52.5	− .03	21.11	2.06	28.20	54.94
20	C.	52.5	− .03	22.72	1.91	29.24	55.36
21	C.	53.7	− .03	22.69	2.18	29.57	55.27
22	C.	48.4	− .03	20.94	3.67	29.89	54.69
23	C.	46.2	− .03	21.73	3.54	30.20	55.04
29	C.	23.1	− .03	14.46	12.55	31.89	55.09
Oct. 5	C.	15.4	− .03	13.40	14.69	33.24	54.82
7	C.	19.1	− .03	15.29	13.07	33.62	54.71
10	C.	26.9	− .03	18.64	11.02	34.11	55.52
11	C.	15.8	− .03	13.17	16.32	34.25	55.21
15	C.	6.8	− .03	12.01	17.85	34.72	55.11
19	C.	15.2	− .03	14.82	14.78	35.03	54.54
20	C.	19.3	− .03	17.88	12.62	35.08	55.39
22	C.	+ 9.4	−0.03	+5 12.35	+3 17.57	−0 35.15	54.74

$D = 120° \ 7' \ 54''.00$

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
"	"	"	"					"	
+0.02	−0.34	....	....	....	....	....	0.	....	1891. June 11
.02	.34	....	−1.12	−1.08	−0.63	+1.77	0.5	−0.95	13
.02	.50	....	−1.04	−1.03	−0.57	1.77	0.5	− .87	15
.02	.22	−0.44	+0.41	+1.10	+1.63	0.92	0.5	+ .45	Sept. 8
.02	.40	.46	−0.08	1.20	1.70	0.78	1.	− .04	8
.02	.32	.46	+0.49	1.23	1.72	0.75	0.5	+ .52	9
.02	.35	.47	−0.26	1.29	1.75	0.66	1.	− .23	12
.02	.36	.47	−0.40	1.31	1.77	0.62	1.	− .37	13
.02	.50	.48	+0.16	1.34	1.79	0.56	1.	+ .19	15
.02	.61	.49	+0.14	1.38	1.81	0.50	1.	+ .17	17
.02	.59	.50	−0.29	1.43	1.84	0.40	0.5	− .26	20
.02	.54	.50	−0.25	1.45	1.85	0.37	1.	− .22	21
.02	.50	.49	+0.28	1.47	1.86	0.33	1.	+ .31	22
.02	.52	.49	−0.05	1.48	1.87	0.29	1.	− .02	23
.02	.31	.47	−0.33	1.55	1.90	+0.09	1.	− .30	29
.02	.19	.47	−0.18	1.62	1.92	−0.11	0.5	− .15	Oct. 5
.02	.28	.48	+0.03	1.64	1.92	0.18	1.	+ .06	7
.02	.32	.49	−0.73	1.67	1.91	0.28	1.	− .70	10
.02	.23	.47	−0.53	1.67	1.91	0.31	1.	− .50	11
.02	.15	.47	−0.51	1.70	1.89	0.44	1.	− .47	15
.02	.20	.47	+0.11	1.71	1.86	0.56	1.	+ .15	19
.02	.21	.48	−0.72	1.71	1.86	0.60	1.	− .68	20
+0.02	−0.13	−0.47	−0.16	+1.72	+1.84	−0.66	1.	−0.12	22

C (3). *U* Ophiuchi. *f* Piscium.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Sep. 23	F.	+23.6	+0.35	+6 26.63	+3 14.00	−0 21.07	19.91
28	C.	+24.2	+ .35	32.77	14.73	23.27	24.58
30	C.	+25.2	+ .35	35.38	13.07	24.06	24.74
Oct. 14	C.	+13.9	+ .35	38.93	14.32	28.89	24.71
17	F.	+20.3	+ .35	39.53	13.83	29.73	23.48
18	C.	+13.2	+ .23	38.04	15.99	29.98	24.28
20	C.	+15.2	+ .35	39.37	16.32	30 47	25.57
21	F.	+12.3	+ .47	6 34.26	17.47	− 30.70	21.50
1891. July 15	C.	+33.7	− .02	5 59.87	9.60	+ 15.81	25.26
Sept. 7	C.	+25.4	− .02	6 24.56	13.47	− 13.30	24.71
8	C.	+27.4	− .02	24.76	13.29	13.82	24.21
12	C.	+35.9	− .02	31.21	8.81	15.84	24.16
13	C.	+28.5	− .02	28.58	11.92	16.33	24.15
15	C.	+35.5	− .02	32.05	9.14	17.32	23.85
17	C.	+51.4	− .02	39.34	4.03	18.27	25.08
29	C.	+21.0	− .02	32.67	14.92	23.57	24.00
Oct. 15	C.	+ 4.9	− .02	33.28	20.17	29.11	24.32
19	C.	+12.2	−0.02	+6 37.17	+3 17.46	−0 30.16	24.45

D = 120° 9′ 24″.00.

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.05	−0.30	....	....	....	....	....	0.	....	1890. Sept. 23
.05	.25	−0.74	+0.36	+1.13	+1.89	+0.13	1.	−0.04	28
.05	.25	.75	+0.21	1.17	1.90	+0.06	1.	− .19	30
.05	.24	.76	+0.24	1.41	1.90	−0.40	1.	− .16	Oct 14
.05	.23	....	....	....	....	....	0.	....	17
.05	.23	.76	+0.66	1.47	1.87	0.53	0.5	+ .26	18
.05	.23	.77	−0.62	+1.49	1.86	−0.60	1.	−1.02	20
.05	.23	....	....	....	....	....	0.	....	21
.10	.33	.62	−0.41	−0.77	0.38	+1.81	1.	− .74	1891. July 15
.12	.24	.71	+0.12	+0.65	1.69	0.81	1.	− .28	Sept. 7
.12	.39	.71	+0.77	0.67	1.70	0.78	1.	+ .37	8
.12	.32	.73	+0.77	0.77	1.75	0.66	1.	+ .37	12
.12	.35	.72	+0.80	0.80	1.77	0.63	1.	+ .40	13
.12	.47	.74	+1.24	0.85	1.79	0.56	1.	+ .84	15
.12	.56	.77	+0.13	0.89	1.81	0.50	1.	− .27	17
.12	.30	.74	+0.92	1.15	1.90	+0.09	1.	+ .52	29
.12	.18	.74	+0.48	1.42	1.89	−0.44	1.	+ .08	Oct. 15
+0.12	−0.22	−0.76	+0.41	+1.48	+1.86	−0.56	1.	+0.01	19

XVII. B. A. C. 5903. *μ* Piscium.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1890. Oct. 22	C.	+16.4	+0.36	+2 56.79	+3 15.05	−0 29.98	42.23
23	F.	+15.9	.36	56.17	14.66	30.28	40.96
26	C.	+ 5.4	.36	51.03	20.14	30.91	40.62
Nov. 4	C.	+ 2 7	.36	53.52	19.02	32.43	40.47
5	F.	+22.3	.36	61.17	11.71	32.56	40.68
10	C.	+ 0.4	.36	50.13	23.63	33.02	40.10
11	F.	+ 6.7	.36	55.31	19.74	33.08	42.33
12	C.	+ 9.5	.36	56.32	18.62	33.13	42.17
13	F.	+15.7	.36	59.04	14.50	33.17	40.73
18	C.	+14.2	.36	57.78	15.30	33.23	[1]40.21
19	F.	+11.5	.36	56.06	18.07	33.20	41.29
20	C.	+15.8	+ .36	58.39	15.51	− 33.17	41.09
1891. June 10	C.	+27.2	− .02	2 0.74	11.21	+ 30.13	42.06
11	F.	+27.4	.02	1 57.92	12.07	29.89	39.86
13	F.	+36.3	.02	2 3.50	7.94	29.39	40.81
15	F.	+40.7	.02	6.47	6.29	28.86	41.60
21	C.	+32.9	.02	6.70	7.73	27.08	41.49
22	C.	+34.4	.02	6.51	8.83	26.75	42.07
July 3	C.	+30.6	.02	8.82	10.16	22.72	41.68
4	C.	+26.1	.02	6.76	12.39	22.32	41.45
5	C.	+30.3	.02	9.81	10.39	21.91	42.09
9	C.	+24.8	.02	8.48	13.37	20.20	42.03
11	C.	+36.4	.02	14.12	8.24	+ 19.32	41.66
Oct. 20	C.	+17.3	.02	56.16	14.77	− 29.40	41.51
22	C.	+ 7.9	.02	52.94	19.44	29.92	42.44
23	C.	+25.8	−0.02	+2 61.39	+3 11.42	−0 30.16	42.63

[1] Observer notes: "Bad night and poor measures."

D = 120° 5′ 40″.50.

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.31	−0.22	−0.15	−1.04	+1.47	+1.83	−0.66	1.	−0.88	1890. Oct. 22
.31	.22	....	+0.07	1.48	1.83	0.70	0.5	+ .23	23
.32	.11	.14	+0.45	1.52	1.79	0.79	1.	+ .61	26
.32	.10	.15	+0.60	1.58	1 68	1.07	1.	+ .77	Nov. 4
.32	.27	....	+0.41	1.59	1.66	1.10	0.5	+ .58	5
.33	.09	.14	+0.96	1.61	1.58	1.24	1.	+1.13	10
.33	.09	....	−1.41	1.61	1.55	1.27	0.5	−1.23	11
.33	.14	.15	−1.05	1.62	1.53	1.30	1.	− .87	12
.33	.16	....	+0.26	1.62	1.51	1.32	0.5	+ .44	13
.33	.12	.15	+0.89	1.62	1.40	1.45	0.75	+1.08	18
.33	.13	....	−0.83	1.62	1.38	1.47	0.35	− .14	19
.33	.22	.16	+0.13	+1.62	+1.35	−1.50	1.	+ .32	20
.56	.35	.07	−0.58	−1.48	−0.72	+1.74	1.	− .27	1891. June 10
.56	.35	....	....	....	....	....	0.	....	11
.56	.37	....	+0.62	1.44	0.63	1.77	0.25	+ .92	13
.56	.55	....	+0.01	1.41	0.57	1.78	0.5	+ .31	15
.56	.57	.08	+0.22	1.32	0.39	1.81	1.	+ .51	21
.56	.39	.08	−0 54	1.31	0.36	1.81	1.	− .25	22
.57	.34	.08	−0.19	1.11	−0.02	1.84	1.	+ .09	July 3
.57	.32	.08	+0.02	1.10	+0.01	1.84	1.	+ .29	4
.58	.36	.08	−0.57	1.08	0.04	1.84	1.	− .31	
.59	.30	.08	−0.56	0.99	0.16	1.84	1.	− .32	9
.59	.45	.08	−0.04	−0.95	0.22	+1.83	1.	+ .20	11
.70	.20	.15	+0.04	+1.44	1.86	−0.60	1.	+ .21	Oct. 20
.70	.11	.14	−0.99	1.47	1.84	0.66	1.	− .83	22
−0.70	−0.32	−0.16	−0.95	+1.48	+1.82	−0.70	1.	−0.79	23

XVII. B. A. C. 5903. μ Piscium.—Continued.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ "	′ "	′ "	"
1891. Oct. 26	C.	+15.4	−0.02	+2 55.85	+8 16.70	−0 30.85	41.68
28	C	+19.5	.02	58.65	14.54	31.26	41.91
Nov. 2	C.	+ 3.4	.02	51.19	23.93	32.12	41.98
5	C.	+12.5	.02	57.35	17.00	32.52	41.81
8	C.	+15.0	−0.02	+2 60.61	+8 14.10	−0 32.84	41.85

D (3) Ll. 32200. B. D. − 0°, 258.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ "	′ "	′ "	"
1890. Sep. 21	F.	+24.3	+0.22	−0 56.63	+8 12.30	−0 19.17	56.72
22	C.	+25.7	+ .35	0 56.59	11.60	− 19.65	[1]55.71
1891 July 11	C.	+36.1	− .02	1 30.19	7.73	+ 20.25	57.77
13	C.	+39.1	− .02	29.56	6.05	19.31	[2]55.78
14	C.	+29.0	− .02	31.41	10.11	18.83	57.51
15	C.	+34.2	− .02	29.92	8.64	+ 18.34	57.04
Sep 7	C.	+25.0	− .02	3.45	12.79	− 11.69	57.63
8	C.	+25.5	− .02	1 3.37	13.17	12.24	57.54
12	C.	+35.5	− .02	0 56.01	8.14	14.41	57.70
13	C.	+28.1	− .02	58.38	11.25	14.98	57.92
15	C.	+34.2	− .02	55.14	8.82	15.99	57.67
17	C.	+50.5	− .02	48.56	3.57	17.03	57.96
21	C.	+52.9	− .02	46.54	3.30	19.04	57.70
Nov. 2	C.	+ 0.9	− .02	51.92	22.90	33.41	57.85
17	C.	−18.9	− .02	57.72	30.15	34.61	57.80
24	C.	−13.0	−0.02	−0 54.09	+8 24.02	−0 34.36	[3]55.55

[1] Bright moonlight. Stars faint and difficult. [2] Much lightning. [3] Stars very faint and observation difficult. These stars are at all times peculiarly difficult to observe on account of their faintness.

D = 120° 5′ 40″.50

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.70	−0.16	−0.15	−0.17	+1.51	+1.79	−0.79	1.	−0.01	1891. Oct. 26
.71	− .17	.16	−0.37	1.53	1.77	0.85	1.	− .21	28
.71	− .09	.14	−0.54	1.57	1.71	1.01	1.	− .37	Nov. 2
.71	− .17	.16	−0.27	1.59	1.66	1.10	1.	− .10	5
−0.71	− 23	−0.16	−0.25	+1.60	+1.61	−1.18	1.	− .08	8

D = 120° 1′ 57″.00.

″	″	″	″					″	
−0.02	−0.36	....	+0.66	+0.94	+1.85	+0.37	0.25	+0.63	1890. Sept. 21
.02	− .36	+0.02	+1.65	+0.96	1.85	0.33	0.5	+1.62	22
.04	− .51	.04	−0.26	−0.99	0.22	1.83	1.	− .21	1891. July 11
.04	− .58	.04	+1.80	0.95	0.28	1.82	0.5	+1.84	13
.04	− .40	.04	−0.11	0.92	0.31	1.82	1.	− .07	14
.04	− .44	.04	+0.40	−0.90	0.33	1.82	1.	+ .44	15
.05	− .38	.02	−0.32	+0.57	1.69	0.81	1.	− .35	Sept. 7
.05	− .43	.02	−0.08	0.60	1.70	0.78	1.	− .11	8
.05	− .44	.02	−0.28	0.70	1.75	0.66	1.	− .26	12
.05	− .41	.02	−0.48	0.73	1.77	0.62	1.	− .51	13
.05	− .58	.01	−0.05	0.78	1.79	0.56	1.	− .08	15
.05	− .79	.01	−0.13	0.83	1.81	0.50	1.	− .16	17
.05	− .74	.01	+0.08	0.93	1.85	+0.37	1.	+ .05	21
.05	− .01	.01	−0.50	1.63	1.71	−1.01	1.	− .52	Nov. 2
.05	+ .11	.02	−0.88	1.69	1.43	1.42	1.	− .88	17
−0.05	+0.08	+0.01	+1.41	+1.68	+1.25	−1.59	0.5	+1.43	24

XIX. ι Coronae. A² Aquarii.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	′ "	′ "	′ "	"
1890. Oct. 18	C.	+13.4	+0.35	+6 19.47	+3 15.93	−0 30.07	5.68
26	C.	+ 5.1	.35	15.02	20.45	30.52	5.30
Nov. 4	C.	+ 1.7	.35	16.38	19.54	30.31	5.96
13	F.	+15.0	.35	19.20	14.92	29.37	5.10
19	F.	+10.5	.35	14.24	18.60	28.33	4.86
20	C.	+15.2	.35	18.40	15.85	28.13	6.47
21	F.	+15.0	.35	17.18	16.82	27.91	6.44
23	F.	+ 8.8	+ .35	6 15.99	18.59	− 27.45	7.48
1891. June 21	C.	+32.5	− .02	5 40.90	8.07	+ 17.55	6.50
22	C.	+34.0	.02	39.48	9.15	17.13	5.74
28	C.	+32.8	.02	42.51	8.32	14.53	5.34
July 3	C.	+29.8	.02	43.12	10.59	12.25	5.94
4	C.	+25.5	.02	5 42.02	12.79	+ 11.79	6.58
Oct. 15	C.	+ 3.7	.02	6 15.54	20.63	− 29.73	6.42
19	C.	+11.5	.02	17.85	17.69	30.14	5.38
20	C.	+16.4	.02	21.60	15.23	30.22	6.59
23	C.	+24.3	.02	24.93	12.11	30.41	6.61
Nov. 1	C.	+ 2.3	.02	13.15	23.01	30.48	5.66
10	C.	+ 8.8	− .02	+6 20.39	+3 14.97	−0 29.80	5.54

$D = 120° \; 9' \; 5''.00$

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.03	−0.22	−0.70	+0.27	+1.47	+1.87	−0.53	1.	+0.28	1890. Oct 18
.03	.15	.68	+0.56	1.50	1.79	0.79	1.	+ .57	26
.03	.14	.68	−0.11	1.49	1.68	1.07	1.	− .09	Nov. 4
.03	.13	....	+0.06	1.44	1.51	1.32	0.5	+ .09	13
.04	.19	....	+0.37	1.39	1.38	1.47	0.5	+ .41	19
.04	.23	.69	−0.51	1.38	1.35	1.50	1.	− .46	20
.04	.23	....	−1.17	+1.37	+1.33	−1.52	0.5	−1.12	21
.04	.17	....	....	....	....	....	0.	....	23
.06	.52	.56	−0.36	−0.86	−0.39	+1.81	1.	− .23	1891. June 21
.06	.34	.56	+0.22	0.84	0.36	1.81	0.5	+ .39	*a* 22
.06	.45	.57	+0 74	0.71	0.18	1.84	0.5	+ .85	*b* 28
.06	.30	.57	−0.01	0.60	−0.03	1.84	1.	+ .09	July 3
.08	.30	.57	−0.63	−0.58	+0.01	+1.84	1.	− .53	4
.08	.17	.68	−0.49	+1.46	1.89	−0.44	1.	− .48	Oct. 15
.08	.21	.68	+0.59	1.48	1.86	0.56	1.	+ .60	19
.08	.21	.70	−0.60	1.48	1.85	0.60	0.5	− .59	20
.08	.30	.71	−0.52	1.49	1.83	0.70	1.	− .51	23
.08	.14	.67	+0.23	1.49	1.72	0.98	1.	+ .24	Nov. 1
−0.08	−0.15	−0.70	+0.39	+1.46	+1.57	−1.24	1.	+0.41	10

a Incomplete observation. Micrometer thread buckled. *b* Observer notes: Difficult and unsatisfactory observation.

XX. 5 H. Scuti. γ Ceti.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	' "	' "	' "	"
1890. Oct. 23	F.	+15 6	+0.49	+2 45.83	+3 14.02	+0 27.65	32.69
Nov. 5	F.	+15.6	+ .35	49.89	13.18	31.88	31.04
10	C.	− 0.9	+ .35	41.91	22.41	33.10	31.57
11	F.	+ 5.6	+ .35	46.49	19.45	33.32	32.97
12	C.	+ 7.2	+ .35	44.99	18.84	33.53	30.65
13	F.	+14.4	+ .35	49.34	14.30	33.72	30.27
19	F.	+10.5	+ .35	47.58	17.63	34.67	30.89
20	C.	+14 2	+ .35	49.87	15.36	34.79	30.79
21	F.	+14.5	+ .35	49.46	16.23	34.89	31.15
23	F.	+ 6.8	+ .35	48.34	18.15	35.08	31.76
27	F.	+ 0.4	+ .35	2 45.21	21.46	− 35.33	31.69
1891. June 21	C.	+32.4	− .03	1 50.68	7.23	+ 32.97	a 30.85
23	C.	+33.3	− .03	50.12	8.53	32.75	31.37
July 3	C.	+29.4	− .03	52.29	9.83	29.76	31.85
4	C.	+25.8	− .03	50.71	11.79	29.44	31.91
5	C.	+29.5	− .03	52.64	9.87	29.11	31.59
9	C.	+23.6	− .03	51.01	12.98	27.71	31.67
13	C.	+37.5	− .03	58.51	6.59	26.20	31.27
14	C.	+28.8	− .03	56.01	10.10	25.79	31.87
15	C.	+34.2	− .03	57.74	8.50	25.39	31.60
18	C.	+28.2	− .03	57.71	10.07	24.13	31.88
20	C.	+26.6	− .03	1 56.90	12.03	23.26	32.16
22	C.	+40.0	− .03	2 3.01	6.28	+ 22.36	31.62
Nov. 1	C.	+ 1.9	− .03	39.33	22.26	− 30.66	30.90
8	C.	+13.0	− .03	49.30	14.14	32.58	30.83
10	C.	+ 7.1	−0.03	+2 50.17	+3 14.71	−0 33.05	31.80

a Incomplete observation. Micrometer coincidence not eliminated.

D = 120° 5′ 31″.50.

μ	r	φ(d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.15	−0.21	....	....	....	....	... .	0.	....	1890. Oct. 23
.15	.21	....	+0.53	+1.55	+1.66	−1.10	0.5	+0.37	Nov. 5
.15	.09	−0.12	−0.01	1.61	1.58	1.24	1.	- .14	10
.16	.13	....	....	... .	....	....	0.	....	11
.16	.13	.13	+0.94	1.64	1.53	1.29	1.	+ .81	12
.16	.12	....	....	....	....	....	0.	... .	13
.16	.12	....	+0.57	1.39	1.38	1.47	0.5	+ .44	19
.16	.22	.14	+0.91	1.70	1.35	1.49	1.	+ .79	20
.16	.22	....	+0.41	1.70	1.33	1.52	0.5	+ .29	21
.16	.10	....	−0.32	1.71	1.27	1.56	0.5	− .44	23
.16	.08	....	−0.27	+1.73	+1.17	−1.65	0.5	− .38	27
.27	.58	.06	+1.02	−1.61	−0.39	+1.81	0.5	+ .99	1891. June 21
.27	.40	.06	−0.32	1.60	0.36	1.82	1.	+ .28	22
.27	.35	.06	−0.21	1.46	−0.03	1.84	1.	− .27	July 3
.27	.32	.06	−0.30	1.44	+0.01	1.84	1.	− .36	4
.27	.37	.06	+0.07	1.42	0.04	1.84	1.	+ .01	5
.27	.30	.06	−0.08	1.36	0.16	1.84	1.	− .15	9
.28	.51	.07	+0 53	1.28	0.28	1.83	1.	+ .46	13
.28	.37	.07	−0.21	1.26	0.31	1.82	1.	− .28	14
.28	.40	.07	+0.09	1.24	0.33	1.81	1.	+ .01	15
.28	.30	.07	−0.29	1.18	0.42	1.80	1.	− .37	18
.28	.38	.07	−0.49	1.13	0.48	1.78	1.	− .57	20
.28	.55	.07	+0.22	−1.10	0.55	+1.77	1.	+ .13	22
.33	.08	.12	+0.47	+1.50	1.72	−0.98	1.	+ .31	Nov. 1
.33	.23	.14	+0.71	1.59	1.61	1.19	1.	+ .56	8
+0.33	−0.12	−0.14	−0.37	+1.61	+1.57	−1.24	1.	−0.52	10

XX. 5 H. Scuti. *γ* Ceti. — Continued.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	″	′ ″	′ ″	′ ″	″
1891. Nov.17	C.	−19.0	−0.03	+2 35.48	+3 30.13	−0 34.35	31.23
28	C.	−25.2	.03	35.33	31.82	35.35	31.77
29	C.	−24.2	.03	34.25	32.23	35.38	31.07
Dec. 5	C.	− 4 9	.03	2 44.51	21.61	− 35.29	30.83
1892. June 29	C.	+25.3	.03	1 50.24	11.00	+ 30.75	31.96
July 4	C.	+29.0	.03	51.31	11.50	29.19	31.97
5	C.	+30.0	.03	50.06	12.19	28.85	31.07
6	C.	+30.4	.03	51.16	12.42	28.51	32.06
11	C.	+40.1	−0.03	+1 58.62	+3 6.06	+0 26.68	31.33

E (3). *g* Aquilae. *α* Ceti.

		div.	″	′ ″	′ ″	′ ″	″
1890. Aug.29	F.	+29.2	+0.35	−3 30.50	+3 10.17	+0 5.27	45.29
30	F.	+25.0	.35	33.45	12.43	4.69	44.02
31	F.	+28.6	.35	31.63	11.02	4.10	43.84
Sept. 6	F.	+46.4	.35	19.89	2.79	+ 0.54	43.79
10	F.	+26.4	.35	25.91	11.62	− 1.84	44.22
16	F.	+13.2	.35	25.76	16.26	5.41	45.44
21	F.	+23.0	.35	19.21	12.66	8.88	45.42
22	C.	+24.3	.35	18.89	11.90	8.95	44.41
23	F.	+20.9	.35	18.02	14.28	9.54	47.07
27	F.	+11.0	.35	21.74	19.10	11.83	45.88
28	C.	+16.8	.35	19.94	16.42	12.40	44.43
29	F.	+22.8	+0.35	−3 15.16	+3 13.93	−0 12.96	46.16

D = 120° 5′ 31″.50

μ	r	φ (d)	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.34	−0.02	−0.13	+0.07	+1.68	+1.43	−1.42	1.	−0.06	1891. Nov 17
.35	.00	.13	−0.50	1.73	1.14	1.67	1.	− .61	28
.35	− .01	.12	+0.21	1.73	1.12	1.69	1.	+ .11	29
.35	− .06	.13	+0.51	+1.72	+0.95	−1.81	1.	+ .41	Dec. 5
.45	− 30	.06	−0.55	−1.51	−0.15	+1.84	1.	− .60	1892. June 29
.45	− .37	.06	−0.49	1.43	0.00	1.84	1.	− .55	July 4
.45	− .38	.06	+0.42	1.41	+0.04	1.84	1.	+ .36	5
.45	− .39	.06	−0.56	1.40	0.07	1.84	1.	− .63	6
+0.46	−0.60	−0.07	+0.38	−1.30	+0.22	+1.83	1.	+0.31	11

D = 119° 59′ 45″.00.

″	″	″	″					″	
+0.04	−0.28	......	−0.05	−0.24	+1.55	+1.05	0.5	−0.46	1890. Aug. 29
.04	− .26	......	+1.20	0.23	1.56	1.03	0.5	+ .79	30
.04	− .28	......	+1.40	0.20	1.58	1.00	0.5	+ .99	31
.05	− .77	......	+1.93	−0.02	1.67	0.84	0.5	+1.51	Sept. 6
.05	− .37	......	+1.10	+0.09	1.73	0.72	0.5	+ .68	10
.05	− .17	......	−0.32	0.27	1.80	0.53	0.5	− .74	16
.05	− .34	......	−0.13	0.41	1.84	0.38	0.5	− .55	21
.05	− .38	+0.19	+0.73	0.44	1.85	0.33	1.	+ .31	22
.05	− .30	......	......	......	......	......	0.	......	23
.05	− .09	......	......	......	......	......	0.	......	27
.05	− .22	+0.19	+0.55	+0.61	+1.89	+0.13	1.	+0.13	28
+0.05	−0.28	......	......	......	......	......	0.	......	29

E (3). *g* Aquilae. *α* Ceti.—Continued.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	' "	' "	' "	"
1890. Oct. 14	C.	+13.2	+0.35	−3 8.68	+3 13.87	−0 20.90	44.64
18	C.	+13.3	+ .35	8.93	15.17	22.82	43.77
20	C.	+12.6	+ .35	8.37	16.40	23.73	44.65
22	C.	+11.8	+ .35	8.30	15.94	24.62	43.37
26	C.	+ 5.5	+ .35	9.45	19.44	26.31	44.03
Nov. 4	C.	+ 1.7	+ .35	5.15	18.53	29.66	44.07
11	F.	+ 5.2	+ .35	3 3.78	19.64	31.78	44.43
19	F.	+11.4	+ .35	2 59.20	17.48	− 33.60	45.08
1891 July 11	C.	+36.6	− .02	3 51.79	7.53	+ 29.10	44.82
13	C.	+35.5	− .02	50.74	7.17	28.42	44.83
14	C.	+28.6	− .02	53.12	10.25	28.07	45.18
15	C.	+34.0	− .02	50.46	8.68	27.71	45.86
18	C.	+27.8	− .02	52.11	10.26	26.60	44.73
20	C.	+26.9	− .02	53.32	11.95	25.82	44.43
22	C.	+39.8	− .02	46.44	6 42	+ 25.01	44.97
Oct. 15	C.	+ 1.6	− .02	14.65	20.58	− 21.23	44.68
23	C.	+22.2	− .02	2.97	11.68	24.91	43.78
Nov. 1	C.	+ 1.6	− .02	3 9.66	22.46	28.48	44.30
10	C.	+ 6.2	− .02	2 58.41	15.09	31.38	45.28
28	C.	−25.7	− .02	73 63	32.13	34.79	43.69
29	C.	−25.3	− .02	73.60	32.69	34.89	44.18
Dec. 5	C.	− 5.0	− .02	63.55	21.77	35.20	[1]43.00
10	C.	+ 8.1	− .02	57.52	18.36	− 35.16	45.66
1892. June 29	C.	+25.2	− .02	57.70	11.16	+ 32.27	45.71
July 4	C.	+28.5	− .02	57.80	11.78	30.99	44.95
5	C.	+30.0	− .02	57.92	12.25	30.71	45.02
6	C.	+31.0	−0.02	−3 57.87	+3 12.31	+0 30.42	44.88

[1] Seen at intervals through gathering clouds.

$D = 119° \ 59' \ 45''.00$

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
"	"	"	"					"	
+0.05	−0.17	+0.17	+0.31	+1.03	+1.90	−0.40	1.	−0.11	1890. Oct. 14
.06	.17	.17	+1.17	1.11	1.88	0.53	1.	+ .76	18
.06	.17	.17	+0.29	1.16	1.85	0.60	1.	− .12	20
.06	.17	.17	+1.57	1.20	1.83	0.66	1.	+1.16	22
.06	.03	.17	+0.77	1.29	1.79	0.79	1.	+ .36	26
.06	.01	.17	+0.71	1.45	1.68	1.07	1.	+ .31	Nov. 4
.06	.03	....	+0.54	1.55	1.55	1.27	1.	+ .13	11
.06	.17	....	+0.08	+1.64	1.38	−1.47	1.	− .30	19
.11	.55	.26	+0.36	−1.42	0.22	+1.83	1.	+ .03	1891. July 11
.11	.58	.26	+0.38	1.39	0.28	1.82	1.	+ .05	13
.11	.41	.27	−0.15	1.37	0.30	1.82	1.	− .48	14
.12	.47	.26	−0.77	1.35	0.33	1.81	1.	−1.11	15
.12	.33	.26	+0.22	1.30	0.42	1.79	1.	− .12	18
.12	.42	.27	+0.60	1.26	0.48	1.78	1.	+ .26	20
.12	.66	.25	+0.32	−1.22	0.54	+1.76	1.	− .02	22
.12	.12	.18	+0.14	+1.04	1.89	−0.44	1.	− .27	Oct. 15
.12	− .31	.16	+1.25	1.22	1.83	0.70	1.	+ .84	23
.13	+ .03	.17	+0.37	1.39	1.65	0.98	1.	− .05	Nov. 1
.13	.04	.16	−0.61	1.54	1.57	1.21	1.	−1.02	10
.13	.25	.18	+0.75	1.70	1.15	1.67	1.	+ .38	28
.13	.25	.18	+0.26	1.71	1.12	1.69	1.	− .10	29
.13	+ .08	.16	+1.63	1.72	0.95	1.81	0.5	+1.27	Dec. 5
.13	− .04	.15	−0.90	+1.72	+0.80	−1.88	1.	−1.25	10
.16	.36	.16	−0.67	−1.57	−0.15	+1.84	1.	− .98	1892. June 29
.16	.40	.16	+0.13	1.52	+0.01	1.84	1.	− .19	July 4
.16	.43	.16	+0.09	1.51	0.04	1.84	1.	− .23	5
+0.16	− 0.45	+0.16	+0.25	−1 49	+0.07	+1.84	1.	−0.08	6

XXI. ν Aquilae. *f* Tauri.

Date.	Obs'r.	Temp.	K	d	R	A	Δ
		div.	"	′ ″	′ ″	′ ″	″
1890. Nov. 5	F.	+14.3	+0.36	+4 47.03	+3 14.69	−0 25.40	36.68
10	C.	− 2.1	.36	40.44	23.95	27 28	37.47
12	C.	+ 5.8	.36	44.44	20.49	27.98	37.31
13	F.	+13.5	.36	48 97	15.71	28.32	36.72
18	C.	+12.4	.36	50.31	16.50	29.88	37.29
20	C.	+13 0	.86	51.15	16.94	30.44	38.01
21	F.	+13.4	.36	50.65	17.88	30.70	38.19
23	F.	+ 5.5	.36	48.62	19.58	31.20	37.36
27	F.	− 1.0	.36	47.50	23.14	32.10	38.90
Dec. 9	F.	− 4.0	.36	51.40	20.00	33.80	37.96
17	F.	− 3.2	+ .36	4 46.17	24.34	− 34.10	36.77
1891. July 3	C.	+29.5	− .02	3 53.95	10.92	+ 32 67	37.52
4	C.	+26.0	.02	53.20	12.82	32.51	38.51
5	C.	+28.8	.02	54.15	11.12	32.34	37.59
9	C.	+23.1	.02	51.77	14.30	31.55	37.60
11	C.	+36.2	.02	58.09	8.70	31.10	37.87
13	C.	+34.6	.02	59.39	8.51	30.62	38.50
14	C.	+28.2	.02	55.51	11.45	30.36	37.30
15	C.	+33.5	.02	57.93	9.79	30.10	37.80
18	C.	+27.0	.02	57.00	11.58	29.27	37.83
20	C.	+26.9	.02	3 55.95	12.98	28.67	37.58
22	C.	+39.3	.02	4 2.53	7.60	+ 28.04	38.15
Nov.17	C.	−19.5	.02	35.88	31.56	− 29.51	37.91
28	C.	−26.1	.02	36.49	33.40	32.25	37.62
29	C.	−26.0	.02	36.14	34.09	32.43	37.78
Dec. 1	C.	+ 2.0	−0.02	+4 53.33	+3 18.59	−0 32.79	[1]39.11

[1] A hurried set of measures.

D = 120° 7′ 37″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.02	−0.18	....	+0.52	+1.24	+1.66	−1.10	0.5	+0.64	1890. Nov. 5
.02	.14	−0.38	+0.07	1.33	1.58	1.25	1.	+ .20	10
.02	.16	.39	+0.26	1.37	1.53	1.27	1.	+ .39	12
.02	.13	....	+0.43	1.39	1.51	1.32	0.5	+ .73	13
.02	.13	.40	+0.26	1.46	1.40	1.45	1.	+ .56	18
.02	.23	.40	−0.36	1.49	1.35	1.50	1.	− .21	20
.02	.17	....	−1.00	1.50	1.33	1.54	0.5	− .85	21
.02	.16	....	−0.18	1.53	1.27	1.56	0.5	− .03	23
.02	.14	....	....	....	....	....	0.	....	27
.02	.13	....	−0.81	1.65	0.82	1.87	0.5	− .64	Dec. 9
.03	.13	....	+0.39	+1.66	+0.56	−1.99	0.5	+ .58	17
.04	.33	.27	+0.12	−1.59	−0.02	+1.84	1.	+ .38	1891. July 3.
.04	.32	.27	−0.88	1.59	+0.01	1.84	1.	− .67	4
.04	.35	.27	+0.07	1.58	0.04	1.84	1.	+ .28	5
.04	.29	.26	−0.01	1 55	0.16	1 84	1.	+ .19	9
.04	.42	.28	−0.13	1.52	0.22	1.84	1.	+ .07	11
.04	.47	.28	−0.71	1.50	0.28	1.83	1.	− .52	13
.04	.35	.27	+0.36	1.49	0.31	1.83	1.	+ .55	14
.04	.37	.28	−0.11	1.47	0.33	1.82	1.	+ .08	15
.04	.28	.28	−0.23	1.43	0.42	1.80	1.	− .04	18
.04	.37	.27	+0.10	1.40	0.48	1 78	1.	+ .29	20
.04	.51	.28	−0.32	−1.37	0.54	+1.77	1.	− .14	22
.05	.10	.37	−0.39	+1.45	1.43	−1.42	1.	− .25	Nov. 17
.05	.09	.37	−0.11	1.57	1.15	1.67	1.	+ .05	28
.05	.09	.37	−0.27	1.58	1.12	1.69	1.	− .11	29
−0.05	−0.18	−0.41	−1.47	+1.60	+1.06	−1.73	0.5	−1.30	Dec. 1

XXI. ν Aquilae. *f* Tauri.—Continued.

Date.	Obs'r.	Temp.	*K*	*d*	*R*	*A*	*Δ*
		div.	"	′ "	′ "	′ "	"
1891. Dec. 5	C.	− 5.1	−0.02	+4 47.26	+3 22.95	−0 33.37	36.82
10	C.	+ 8.4	.02	52.41	19.36	33.85	37.90
11	C.	+ 5.7	.02	49.21	23.12	33.92	38.39
12	C.	+ 6.6	.02	51.11	20.97	33.98	38.08
16	C.	− 7.7	.02	46.67	24.90	34.10	37.45
17	C.	−12.6	.02	42.68	28.95	34.10	37.51
18	C.	− 4.2	−0.02	+4 46.62	+3 25.62	−0 34.09	38.13

F (3) ι Aquilae. 10 Tauri.

		div.	"	′ "	′ "	′ "	"
1890. Sept. 6	F.	+45.6	+0.35	−0 21.22	+3 3.25	+0 5.07	47.45
16	F.	+12.4	.35	28.36	16.83	− 0.87	47.95
22	C.	+23.4	.35	19.94	12.32	4.50	48.23
27	F.	+10.2	.35	24.69	19.48	7.49	47.65
28	C.	+12 9	.35	22.23	17.95	8.08	47.99
29	F.	+22.9	.22	18.30	14.06	8.66	47.32
Oct. 14	C.	+12.9	.48	9.04	14.12	17.13	48.43
20	C.	+11.8	.35	9.11	16.85	20.26	47.83
21	F.	+10.5	.22	9.42	17.48	20.77	47.51
22	C.	+10.9	.35	7.28	16.48	21.25	48.30
26	C.	+ 6.4	.35	8.25	19.22	23.16	48.16
Nov. 4	C.	+ 4.5	.35	4.63	18.61	27.06	47.27
10	C.	− 2.4	+0.35	−0 5.88	+3 23.14	−0 29.31	48.30

D = 120° 7′ 37″.00

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
−0.05	−0.11	−0.39	+0.73	+1.63	+0.95	−1.81	0.5	+0.90	1891. Dec. 5
.05	.13	.40	−0.32	1.65	0.80	1.88	1.	− .14	10
.05	.15	.40	−0.79	1.66	0.76	1.89	1.	− .61	11
.05	.13	.40	−0.50	1.66	0.71	1.91	1.	− .31	13
.05	.12	.39	+0.11	1.66	0.59	1.96	1.	+ .30	16
.05	.10	.38	+0.02	1.66	0.56	1.98	1.	+ .21	17
−0.05	−0.15	−0.39	−0.54	+1.66	+0 53	−1.98	1.	−0.35	18

D = 120° 2′ 48″.00.

μ	r	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.14	−0.66	....	+1.07	−0.25	+1.67	+0.84	0.5	+1.03	1890. Sept. 6
.15	.17	....	+0.07	+0.04	1.80	0.53	0.5	+ .03	16
.15	.36	0.00	−0.02	0.22	1.85	0.33	1.	− .06	23
.16	.33	....	+0.51	0.37	1.89	0.16	0.5	+ .47	27
.16	.23	.00	+0.08	0.40	1.89	0.13	1.	+ .04	28
.16	.28	....	+0.80	0.42	1.90	+0.10	0.5	+ .76	29
.17	.19	.00	−0.41	0.84	1.90	−0.40	1.	− .44	Oct. 14
.17	.18	.00	+0.18	0.99	1.86	0.60	1.	+ .15	20
.17	.18	....	+0.50	1.02	1.85	0.62	0.5	+ .47	21
.17	.19	.00	−0.28	1.04	1.83	0.66	1.	− .31	22
.18	.07	.00	−0.27	1.13	1.79	0.79	1.	− .30	26
.18	.07	.00	+0.62	1.32	1.68	1.07	1.	+ .59	Nov. 4
+0.19	−0.03	.00	−0.46	+1.44	+1.57	−1.24	1.	− .49	10

F (3). ι Aquilae. 10 Tauri.—Conticued.

Date.	Obs'r.	Temp.	*K*	*d*		*R*		*A*		*Δ*
		div.	″	′	″	′	″	′	″	″
1890. Nov. 11	F.	+ 4.3	+0.35	−0	3.47	+3	20.10	−0	29.66	47.32
12	C.	+ 4 1	.35	−	3.02		20.21		29 98	47.56
13	F.	+12.7	.22	+	3.77		15.15		30.31	48.83
19	F.	+11.4	.22	+	2.83		17.57		32.07	48.55
20	C.	+11.9	.35	+	3.89		16.18		32.33	48.09
27	F.	− 2 5	+ .22	−	1.61		22.69	−	33.86	47.44
1891. July 9	C.	+22.9	− .02		57.38		13.56	+	32 10	48.26
11	C.	+35.6	.02		50.92		8.04		31.59	48.69
13	C.	+33.0	.02		50.41		8.13		31.04	48.74
14	C.	+27.7	.02		53.28		10.72		30.75	48.17
15	C.	+33.0	.02		51.07		9.07		30.45	48.43
18	C.	+26.9	.02		52.74		10.73		29.52	47.49
20	C.	+26.6	.02		53.08		12.14		28.85	47.89
22	C.	+38.7	.02	−	46.65		6.93	+	28.15	48.41
Nov. 10	C.	+ 6.0	.02	+	2.80		15.36	−	29.21	48.93
17	C.	−20.0	.02	−	12.36		30.87		31.45	47.04
28	C.	−26.8	.02	−	11.69		32.81		33.99	47.11
29	C.	−26.8	.02	−	12.23		33.44		34.17	47.02
Dec. 1	C.	+ 2.4	.02	+	4.52		17.61		34.47	47.64
10	C.	+ 8.8	.02	+	4.38		18.32		35.33	47.35
11	C.	+ 4.3	.02	+	0.47		22.73		35.37	47.81
12	C.	+ 5.9	.02	+	2.18		20.27		35.39	47.04
16	C.	− 8.7	.02	−	0.98		24.36		35.40	47.96
17	C.	−12.6	.02	−	5.01		28.02		35.37	47.62
18	C.	− 4.7	.02	−	1.23		24.88		35.33	48.30
23	C.	− 3.0	−0.02	+0	1.51	+3	21.00	−0	34.98	47.51

D = 120° 2′ 48″.00.

μ	τ	$\varphi(d)$	n	f	A	B	p	v	Date.
″	″	″	″					″	
+0.19	−0.08	....	+0.57	+1.45	+1.55	−1.27	0.5	+0.55	1890. Nov. 11
.19	.10	.00	+0.35	1.47	1.54	1.30	1.	+ .33	12
.19	.10	....	−0.92	1.48	1.51	1.33	0.25	− .93	13
.19	.10	....	−0.64	1.56	1.38	1.47	0.25	− .65	19
.19	.20	.00	−0.08	1.58	1.35	1.50	1.	− .08	20
.19	.01	....	+0.38	+1.65	1.17	−1.65	0.5	+ .39	27
.32	.31	+0.02	−0.29	−1.53	0.16	+1.84	1.	− .24	1891. July 9
.32	.49	.01	−0.53	1.55	0.22	1.83	1.	− .48	11
.32	.53	.01	−0.54	1.52	0.28	1.82	1.	− .49	13
.32	.38	.01	−0.12	1.51	0.31	1.82	1.	− .06	14
.32	.43	.01	−0.33	1.49	0.38	1.81	1.	− .29	15
.33	.30	.01	+0.47	1.45	0.42	1.80	1.	+ .51	18
.33	.39	.01	+0.16	1.41	0.48	1.78	1.	+ .20	20
.33	.60	.01	−0.15	−1.38	0.54	+1.77	1.	− .11	22
.41	− .08	.00	−1.26	+1.43	1.58	−1.24	1.	−1.28	Nov. 10
.41	+ .08	.00	+0.47	1.54	1.48	1.42	1.	+ .46	17
.41	+ .10	.00	+0.38	1.66	1.15	1.67	1.	+ .39	28
.42	+ .11	.00	+0.45	1.67	1.12	1.69	1.	+ .46	29
.42	− .09	.00	+0.03	1.68	1.06	1.74	1.	+ .05	Dec. 1
.42	− .08	.00	+0.31	1.73	0.80	1.89	1.	+ .33	10
.42	− .08	.00	−0.15	1.73	0.76	1.90	1.	− .12	11
.42	− .07	.00	+0.61	1.73	0.73	1.91	1.	+ .64	12
.42	.00	.00	−0.38	1.73	0.59	1.96	1.	− .43	16
.42	+ .05	.00	−0.09	1.73	0.55	1.97	1.	− .05	17
.42	− .03	.00	−0.69	1.73	0.52	1.99	1.	− .65	18
+0.43	−0.02	0.00	+0.08	+1.71	+0.34	−2.05	1.	+0.13	23

DISCUSSION OF THE OBSERVATIONS.

The numbers contained in the column Δ of the preceding table when corrected for the effect of proper motion, μ, constitute the data from which values of the aberration and refraction are to be derived, but the effect of several sources of error requires to be taken into account before the observations can be discussed for this purpose.

The column τ contains corrections for the combined effect of four temperature terms, viz.:

(*a*). The effect upon the refraction of the presence of aqueous vapor in the atmosphere.

(*b*). The temperature coefficient of the micrometer.

(*c*). A correction to the coefficient of expansion of air adopted for the γ factor of the Pulkowa Refraction Tables.

(*d*). A correction for defective exposure of the thermometers whose readings were employed for the refraction computations.

The effect upon the refraction of the aqueous vapor contained in the atmosphere has been investigated by Laplace who derives numerical values for its effect and after tabulating them remarks: "*Il résulte de cette table que l' effet de l' humidité de l' air sur la réfraction est très-peu sensible, l'excès de la puissance réfractive de la vapeur aqueuse sur celle de l'air étant compensé en grande partie par sa plus pétite densité.*" *Mec. Cél., Vol. IV, Book X, Chapter 1.* This remark of Laplace's seems to be at least partially justified by an investigation of C. A. F. Peters, who found that observations of Polaris with the Pulkowa vertical circle, when made through clouds, furnished a latitude $0''.04$ greater than that derived from observations made in a clear sky. *Recueil de Mémoirs, etc., par W. Struve, Vol. I, p. 142.*

I know no other foundation than the above for the common practice of assuming the effect of humidity upon the refraction to be insensible, and the evidence thus adduced seems open to the following criticism: The observations of Peters which were made through clouds were distributed throughout the year, and their effect upon the latitude was discussed without any reference to the temperature at which they were made. It is apparent that the effect of humidity will be most pronounced at high temperatures, and during the winter months it will have but a small fraction of the maximum effect which it attains in the summer. Peters' discussion, therefore, seems ill adapted to bring out the real effect of the humidity, and in justice to

him it should be stated that he does not appear to have intended to investigate this effect, since he expressly states: "*Il faut voir si les nuages, surtout par leur influence sur les températures de l'air, ne tendent pas á changer les réfractions,*" *etc.*

As for the investigation of Laplace, it is based upon the theoretical physics of his day, and involves assumptions which are not tenable at the present time. In particular, his value of the index of refraction of aqueous vapor is derived from the index of refraction of water by means of the assumed relation.

$$n^2 - 1 \div d = c$$

where c is a constant, n denotes the index of refraction and d the density of water, whether in the liquid or the gaseous state. Although a certain amount of countenance is given to this equation by the undulatory theory of light, it is not necessarily involved in the theory and the experiments of Gladstone, Dale, and others, discredit it. In particular it should be noted that the equation in the hands of Laplace furnishes for aqueous vapor a refractive power greater than that of air, while laboratory experiments furnish a smaller value for its index of refraction. Thus the *Annuaire du Bureau des Longitudes* for the year 1892 gives upon the authority of Mascart, the value 1.000257, while in Mascart's *Traité d'Optique* the value is given as 1.0002574, and attributed to Fizeau. The index of refraction of dry air is given by Mascart as 1.0002945. From the standpoint of modern physics, therefore, the refraction should be less in a humid than in a dry atmosphere, while Laplace's corrections tend in the opposite direction.

To determine the effect of the aqueous vapor corresponding to the numerical values above given, I denote by n_1 and n_2 the indices of refraction of air and aqueous vapor respectively at a temperature of t_0, $C.$, and pressure of 760 *mm*, and denote the respective coefficients of expansion by m_1 and m_2. The refraction corresponding to any zenith distance z is then given by the equation

$$\mathrm{R} = \frac{n_1 - 1}{\sin 1''} \cdot \frac{b_1}{760} \cdot \frac{1 + m_1 t_0}{1 + m_1 t} \tan z + \frac{n_2 - 1}{\sin 1''} \cdot \frac{b_2}{760} \cdot \frac{1 + m_2 t_0}{1 + m_2 t} \tan z \tag{68}$$

in which the two terms of the second member represent the refractions produced by the air and by the aqueous vapor at pressures of b_1 and b_2 *mm* respectively.

The coefficient

$$n_1 - 1 \div \sin 1'',$$

commonly called the constant of refraction, is replaced in the refraction tables by the quantity α, Bessel's notation. The relation between the two quantities is very approximately

$$\alpha = \frac{n_1 - 1}{\sin 1''} \left(1 - \varepsilon \tan^2 z\right)$$

where ϵ is a small positive quantity. The coefficient $n_2 - 1 \div \sin 1''$

should in strictness be multiplied by a similar variable factor, but since it is also to be multiplied by the small quantity

$$b_2 \div 760$$

the former factor will be neglected. Let b represent the total atmospheric pressure

$$b = b_1 + b_2$$

and we have

$$R = \alpha \frac{b}{760} \cdot \frac{1+m_1 t_0}{1+m_1 t} \tan z - \frac{b_2}{760} \left\{ \frac{n_1 - 1}{\sin 1''} \cdot \frac{1+m_1 t_0}{1+m_1 t} - \frac{n_2 - 1}{\sin 1''} \cdot \frac{1+m_2 t_0}{1+m_2 t} \right\} \tan z \qquad (69)$$

The first term in the second member of this equation is the ordinary expression for the refraction; the second term constitutes a correction to the refraction which may be represented by ΔR. To express this term in a simpler form let us put

$$\frac{(n_1 - 1)(1 + m_1 t_0)}{\sin 1''} = \mu_1 - 1 \qquad \frac{(n_2 - 1)(1 + m_2 t_0)}{\sin 1''} = \mu_2 - 1 \qquad (70)$$

$$\mu_1 - \mu_2 = \omega \qquad (\mu_2 - 1) m_2 - (\mu_1 - 1) m_1 = \psi$$

and obtain

$$\Delta R = -\frac{b_2}{760} (\omega + \psi t) \tan z \qquad (71)$$

To derive numerical values for ω and ψ I adopt the following values of the refractive indices and coefficients of expansion of air and aqueous vapor:

n_1	= 1.0002945	Biot and Arago.
n_2	= 1.0002574	Mascart, Fizeau.
m_1	= 0.003670	Regnault.
m_2	= 0.004187	Hirn, Wüllner.

and find after dividing by 760

$$\Delta R = -b_2 \Big([8.0032 - 10] + [3.8182 - 10] t \Big) \tan z \qquad (72)$$

the square brackets denoting that the numbers placed within them are logarithms. The value adopted for m_2 corresponds to a saturated atmosphere and indicates that the temperature term ψt in ΔR may be entirely neglected.

By means of this expression the effect of the humidity at any zenith distance may be computed, and a comparison of observations made at high temperatures, but under different humidities, will suffice to test the reality of the correction. I have made such a comparison as follows: From the observations with the reel I have selected all those which satisfy the following conditions: The same pair of stars must have been observed at a temperature above 15° C., when the relative humidity was (a) greater than 80, (b) less than 60. Designating these observations by the symbols W (wet) and D (dry) I have formed for each pair of stars the mean difference W — D. There are in all 70 observations of 15 pairs of stars available for this comparison, and from these I find

Uncorrected	$W - D = +0''.17 \pm 0''.08$
Corrected	$W - D = -0.03 \pm 0.06$

Although the quantities involved are small there seems to be little doubt that the effect of the humidity is sensible, and that it is correctly represented by the adopted formula.

I have derived from the records of the meteorological service of this Observatory the values of the vapor tension at the times of observation of all of the pairs of stars and have computed the first part of the correction τ by the formula

$$(a) = -0''.010 \,.\, b_2 \, 2 \tan\frac{\Delta}{2} = -0''.035\, b_2 \qquad (78)$$

where b_2 is the aqueous vapor tension expressed in millimeters.

The average amount of this correction is shown in the following table:

AVERAGE HUMIDITY CORRECTION.

	"		"
March	−0.11	Aug.	−0.38
April	.21	Sept.	.35
May	.24	Oct.	.19
June	.39	Nov.	.12
July	−0.36	Dec.	−0.11

The humidity correction to the refraction may be expressed in a form which for most purposes is more convenient for use with the refraction tables than that given above. We have in Bessel's notation

$$R + \Delta R = (\alpha\beta A\gamma\lambda - \omega b_2)\tan z = Rf$$

where the factor f stands for

$$1 - \frac{\omega b_2}{\alpha\beta A\gamma\lambda} \qquad \text{and}$$

$$\log f = -0.4343\,\omega b_2 \div \alpha\beta A\gamma\lambda$$

Adopting Abbe's formulae, *Report of the Chief Signal Officer for 1887, Part 2, pp. 372 et seq.*, we have as the expression for the aqueous vapor pressure

$$b_2 = p_0 = p_1 - A(\theta_0 - \theta_1)P$$

where p_1 = Elastic pressure of vapor at the temperature θ_1
P = Barometric pressure
θ_0 = Temperature indicated by dry bulb thermometer
θ_1 = Temperature indicated by wet bulb thermometer

The coefficient A of the formula varies slightly with the temperature and depends also upon the particular thermometer employed and the character of its exposure. For the most refined work these elements should be especially investigated and a value of A derived corresponding to them. In the absence of such an investigation a mean value of A may be employed and I have adopted as such a value $A = 0.00080$ which corresponds to a rather poor ventilation such as obtains in the case of a thermometer

placed within a shelter and not whirled. With this value of A and an assumed barometric pressure of 750 *mm.* I have tabulated log f under the form

$$\log f = -\frac{0\ 4343\ \omega}{\alpha\beta_{A}\gamma\lambda}\left\{(p_1 + AP\theta_1) - AP\theta_0\right\} = \frac{E+F}{\beta_{A}\gamma\lambda}$$

The argument for E being the indication of the dry bulb, and for F, of the wet bulb thermometer. The adopted constant value of α corresponds to a zenith distance of 70°

$$R = \alpha\beta_{A}\gamma\lambda f \tan z \qquad \log f = \frac{E+F}{\beta_{A}\gamma\lambda}$$

E Dry Bulb.	Cent.	F Wet Bulb.	
−0.00046	− 10°	+0.00033	
37	8	20	13
27	6	+ 7	13
18	4	− 7	14
− 09	− 2	21	14
00	0	35	14
+ 09	+ 2	50	15
18	4	65	15
27	6	81	16
37	8	98	17
46	10	116	18
55	12	135	19
64	14	155	20
74	16	177	22
83	18	200	23
92	20	225	25
101	22	252	27
110	24	280	28
120	26	311	31
129	28	344	33
+ .00138	+ 30	− .00379	35

E Dry Bulb.	Fah.	F Wet Bulb.	
−0.00055	10°	+0.00046	
42	15	29	17
30	20	+ 11	18
17	25	− 06	19
− 05	30	28	20
+ 08	35	48	20
20	40	69	21
33	45	92	23
46	50	117	25
59	55	144	27
72	60	172	28
85	65	204	32
97	70	240	36
110	75	279	39
+ .00123	80	− .00322	43

The mean effect of aqueous vapor upon the refraction is best exhibited in the form

$$R = \left(\alpha\,\beta\,A\,\gamma\,\lambda - \frac{\omega\, b_2}{760}\right)\tan z = \alpha^1\,\beta\,A\,\gamma\,\lambda \tan z$$

where approximately

$$\log \alpha^1 = \log \alpha - \frac{M}{760}\,\frac{\omega}{\alpha}\, b_2 = \log \alpha - 7.6\, b_2.$$

$M = 0.4343$, b_2 is expressed in millimeters and the coefficient of the last term is in units of the fifth decimal place.

It was not until after the preceding discussion had been made and its results applied to the reduction of the observations that I obtained knowledge of and access to the memoirs of M. Radau contained in the *Annales de l' Observatoire de Paris, Vols. 16* and *19.* The effect of humidity is there investigated and corrections derived which are in substantial agreement with those given above.

The manner in which the humidity corrections vary with the season indicates that the major portion of their effect could be taken into account by modifying the coefficient of expansion of air, and that if this coefficient is determined from astronomical observations which have been reduced without regard to the humidity effect the resulting value should be greater than the true value of the physical constant. Since the coefficient m of the Pulkowa Tables was determined in this manner I have considered it necessary to make a redetermination of its value in order to eliminate from the temperature term so much of the humidity effect as is implicitly contained in it.

If we represent by H the effect of humidity above derived and by c the temperature coefficient of the micrometer screw, we shall have the following expression for the distance between a pair of stars:

$$\Delta = 120^\circ + K + d\left[1 + c(t - t_0)\right] + \alpha\, 2 \tan\frac{\Delta}{2}\,\frac{1 + m\, t_0}{1 + m\, t} - \mathrm{H} \qquad (74)$$

The observations were reduced by the incomplete formula

$$(\Delta) = 120^\circ + K + d + \alpha\, 2 \tan\frac{\Delta}{2}\,\frac{1 + m^1\, t_0}{1 + m^1\, t} \qquad (75)$$

where the accented coefficient m^1 indicates that the assumed coefficient of expansion of air presumably differs from the value m which will best represent the observations. It should also be noted that the adopted temperatures with which the refractions were computed depend upon the indications of the whirled thermometer and that these indications require a correction to reduce them to the indications of the ventilated thermometer, p. 46, expressed by

$$V - W = +\,0^\circ.015\,(t - 17^\circ) \qquad \text{Centigrade} \qquad (76)$$

Adopting the readings of the ventilated thermometer as standard temperature and substituting in place of t and t_0 in equation (75) the symbols w and w_0 to denote that the observations were reduced with these erroneous temperature determinations we have from equation (76) the relation

$$t = \alpha + \beta w \qquad \alpha = -\,0^\circ.25 \qquad \beta = +\,1.015$$

Subtracting (74) from (75) and introducing the expressions just derived we obtain very approximately

$$(\varDelta) - \mathrm{H} = \varDelta + \alpha\, 2 \tan\frac{\varDelta}{2}\, \frac{m\,\beta - m^1}{(1 + m^1\, w)^2}\,(w - w_0) \;-\; c\, d\, \beta\,(w - w_0) \qquad (77)$$

Each erroneous (Δ) after being corrected for the humidity effect will furnish an equation for the determination of the constants c and $m\,\beta - m^1$. To facilitate the computation I put

$$\begin{aligned} &+ (w - w_0)\,\frac{\alpha\, 2 \tan\frac{\varDelta}{2}}{10000\,(1 + m^1\, w)^2} = f \qquad && m\,\beta - m^1 = x + 10000 \\ &- (w - w_0)\,\frac{1}{400} = g && c\,\beta = y + 400 \end{aligned} \qquad (78)$$

and obtain as the form of observation equation

$$+ f\,x + d\,g\,y = (\varDelta) - H - \varDelta \qquad (79)$$

In the formation of the equations d is expressed in minutes of arc.

EQUATIONS FOR THE DETERMINATION OF THE TEMPERATURE EFFECT.

β Piscium	19 Monoc.	$+1.37\,x$	$+2.61\,y$	=	-1.86	6 Obs.
γ Ceti	l Leonis	$+0.93\,x$	$-1.68\,y$	=	-0.95	8
32 Eridani	95 Leonis	$+1.04\,x$	$+1.14\,y$	=	$+3.27$	8
10 Tauri	v Leonis	$+1.07\,x$	$+0.65\,y$	=	$+2.10$	8
μ Tauri	c Virginis	$+0.78\,x$	$-1.02\,y$	=	-0.44	4
π^5 Orionis	α Virginis	$+0.50\,x$	$-0.24\,y$	=	$+0.55$	2
o Orionis	B.D. + 2°, 2664	$+0.84\,x$	$+1.33\,y$	=	$+0.05$	4
ϑ Can. Maj.	ε Bootis	$+2.05\,x$	$+2.76\,y$	=	$+3.08$	8
ε Tauri	ε Corvi	$+2.27\,x$	$-1.85\,y$	=	-0.19	8
119 Tauri	α Virginis	$+3.06\,x$	$-2.71\,y$	=	$+4.24$	12
19 Monoc.	110 Virginis	$+2.23\,x$	$+0.03\,y$	=	$+1.56$	10
γ Geminorum	109 Virginis	$+3.25\,x$	$+0.66\,y$	=	$+2.03$	14
μ Virginis	ς Pegasi	$+1.62\,x$	$-0.69\,y$	=	-1.00	8
37 Librae	70 Pegasi	$+1.18\,x$	$+0.18\,y$	=	-0.78	6
110 Virginis	β Pisc.	$+1.66\,x$	$+1.22\,y$	=	$+0.46$	8
3 Serpentis	φ Aquarii	$+1.87\,x$	$+0.60\,y$	=	-0.27	8
δ Ophiuchi	ι Ceti	$+1.31\,x$	$-2.73\,y$	=	$+1.52$	8
U Ophiuchi	f Piscium	$+0.75\,x$	$-1.05\,y$	=	-0.36	4
B.A.C. 5908	μ Piscium	$+1.51\,x$	$-0.87\,y$	=	$+0.12$	10
Ll. 32200	B.D. −0°, 258	$+1.32\,x$	$+0.26\,y$	=	-0.66	4
ι Coronae	A^2 Aquarii	$+1.24\,x$	$-2.02\,y$	=	-1.01	8
5 H. Scuti	γ Ceti	$+2.58\,x$	$-1.56\,y$	=	-2.12	10
g Aquilae	α Ceti	$+1.91\,x$	$+1.88\,y$	=	$+3.19$	10
ν Aquilae	f Tauri	$+3.55\,x$	$-3.98\,y$	=	-0.45	16
ι Aquilae	10 Tauri	$+3.44\,x$	$+0.20\,y$	=	$+2.40$	16

No. of Equations 25. No. of Observations 208.

To determine numerical values for x and y I have selected from the observations of each pair of stars all those which were separated by a temperature interval greater than 15° C. and from each such observation I have formed an equation of the type given above. These equations, together with the number of observations upon which they are based, are shown in the preceding table.

From the manner in which these equations have been formed it is apparent that they require no further weighting. I have not applied the method of least squares to their solution but have derived normal equations from them by summation as follows:

$$43.33\,x \;-\; 6.88\,y \;=\; +14''.42$$
$$3.13\,x \;+33.92\,y \;=\; +14''.72$$

The solution of which furnishes the values

$$x = +0''.396 \quad \pm 0''.040 \qquad y = +0''.397 \quad \pm 0''.041$$

The probable errors are derived from the first powers of the residuals furnished by the equations.

If we regard x and y as furnishing a system of corrections to the measured distances, it will be convenient to put

$$-\left\{ f x + g d y \right\} = F + G d \tag{80}$$

and to tabulate the quantities F and G with the temperature as argument, as in the following table:

Corr. to $(\Delta) - \mathrm{H} = F + Gd$. ($d$ in minutes of arc).

t	F	G
div.	″	″
−40	+0.19	−0.059
−30	+ .17	− .049
−20	+ .14	− .039
−10	+ .11	− .029
0	+ .08	− .019
+10	+ .04	− .009
+20	.00	+ .001
+30	− .05	+ .011
+40	− .10	+ .021
+50	− .15	+ .031
+60	− .20	+ .041

This table of temperature corrections represents the effect upon the measured distances, of the temperature coefficient of the screw, of the erroneous coefficient of

expansion adopted in the refraction tables, and of the erroneous indications of the whirled thermometer. From it I have interpolated corrections to each observed Δ and the interpolated quantity plus the humidity correction is contained in the column τ of the Tabulated Results of Observation.

From the value of x above derived we obtain

$$\therefore \qquad 1.015\, m = m^1 + 0.0000396.$$

The value of m^1 employed in the Pulkowa Tables is $m^1 = 0.0036894$, and this introduced into the preceding equation gives

$$m = 0.0036738 \quad \pm 0.0000109.$$

This value differs from Regnault's classical determination of the coefficient of expansion of dry air, 0.0036708 by less than half of its own probable error and furnishes a control upon the accuracy with which the several elements entering into its value have been determined; *e. g.* the errors of the temperature determinations and the effect of humidity as well as the difference between the distances measured at high and low temperatures.

It is well known that laboratory determinations of m are capable of furnishing a much better value of this constant than can be derived from astronomical observations since the range of temperature over which the investigation can be extended is much greater in the former than in the latter case. I therefore prefer to put the result of this part of the investigation in the form: The observations with the reel at temperatures between —19° C. and +27° C. are completely satisfied by Regnault's laboratory determination of the coefficient of expansion of air between 0° C. and 100° C.

The preceding investigation contains only observations by Observer C. since it early became apparent that the observations of F. were peculiarly subject to large errors, frequently amounting to several seconds of arc. A portion of these errors have been traced to a confusion of the angles of the reel, *e. g.* one angle being omitted and another used twice in the observation of a pair of stars, but for many of the anomalous results no such explanation is tenable.

While the observations were in progress I made a provisional comparison of the results obtained by the two observers and found that in the mean of all their observations of the same pair of stars no pronounced difference was manifest. But the case is far different where the differences in the measurement of the individual pairs are arranged in the order of magnitude of Δ or, what is equivalent, in the order of magnitude of the micrometer distance d. For such a comparison I have taken the mean of all of F.'s observations of each pair of stars and have subtracted it from the corresponding mean of all of C.'s observations which were approximately simultaneous with those of F.

These differences C.— F. were weighted by the formula

$$p = \frac{2\,m\,n}{2\,m + n}$$

where m and n denote respectively the number of observations by C. and F. and the weighted means

of groups, arranged with reference to the actually measured micrometer distance d, were formed. These mean results are shown in the following table:

Limiting "d"		No. of Pairs.	Weight.	C.—F.	Mean d.	Δ—F.
′	′			″	′	″
−9.0	−7.9	5	11	−0.67	−8.4	+0.55
−4.5	−4.2	3	12	− .43	−4.3	− .10
−4.2	−2.9	4	14	− .60	−3.3	− .41
−2.4	−1.2	3	14	− .21	−1.6	− .16
−0.4	+0.6	3	11	+ .33	−0.3	+ .33
+1.4	+1.9	2	15	+ .42	+1.6	+ .37
+2.3	+2.5	3	14	+ .26	+2.4	+ .16
+3.8	+4.4	3	13	+ .47	+4.1	+ .18
+4.7	+4.8	2	12	+ .13	+4.7	− .26
+5.5	+6.1	4	10	+ .59	+5.8	+ .01

The numbers in the column C.—F. exhibit a marked dependence upon the magnitude of d, showing that at least one of the series of observations is affected with a personal error which is a function of d.

For the investigation of this personal error I have made use of the results of a provisional solution of the equations furnished by all of the pairs of stars. The form adopted for these equations is based upon the assumption that the only errors affecting the observed values of Δ are those resulting from an assumed erroneous value of the constant of aberration, from an erroneous value of the assumed mean refraction, and from a possible annual variation in the amount of the refraction not represented by the ordinary refraction tables.

We may assume the true value of the refraction R, to be represented by an equation of the form

$$R = R_0 (1 + h)(1 + y) \tag{81}$$

where R_0 is the value of the refraction furnished by the tables h is a constant and y a simple harmonic function of the time, whose period is a year. To develop this expression we put

$$y = s \sin (2 \pi t + S) \tag{82}$$

and write

$$\begin{aligned} \alpha &= 100\, s \cos S & \beta &= 100\, s \sin S \\ 100\, A &= -R_0 \sin 2 \pi t & 100\, B &= -R_0 \cos 2 \pi t \end{aligned} \tag{83}$$

where t for any date represents the elapsed fraction of the year. The variable part of the refraction will then be represented by $A\alpha + B\beta$. The effect of an error in the adopted aberration constant is represented by $\frac{k}{k_0} dk = -f x$ where k_0 is the adopted

constant, $dk = x$, its correction, and k the computed effect of the aberration at the instant of observation.

We have therefore as the type of observation equation

$$\Delta_0 + fx + A\alpha + B\beta = \Delta \qquad (84)$$

The absolute terms of the equations are the values of Δ given in the tabular results of observations corrected for the effect of proper motion and increased by approximate values of the correction τ above discussed and for the effect of an assumed value of $h = \frac{1}{150}$ in the equation (81). The individual equations were weighted as follows: Each observation by F. which differed by more than 1″ from the mean of all the observations by C. was given weight 0. Each other observation by F. was given weight 0.5. Each observation by C. was given weight 1.0 unless notes made at the time of observation indicated that it was made under abnormal circumstances in which case it was assigned weight 0.75 or 0.5.

All of the observations of each pair of stars were combined by the method of least squares into normal equations and the first unknown quantity Δ_0 eliminated from these equations. Each reduced normal then contained only three unknown quantities x, α and β which were the same for all of the pairs. The reduced normals corresponding to the several pairs were therefore united by addition into the following group of normal equations for the determination of x, α and β.

Solution I.

$$+1077.61\,x - 170.09\,\alpha - 164.29\,\beta - 44''.89 = 0$$
$$-170.09\,x + 976.38\,\alpha - 431.06\,\beta + 52.49 = 0$$
$$-164.29\,x - 431.06\,\alpha + 644.43\,\beta - 45.03 = 0$$
$$[nn.1] = +167''.55$$

The solution of these equations furnishes the following values of the unknowns, together with their weights:

Unknowns.	Weights.	Prob. Error.
$x = +0''.0507$	922.	$\pm 0''.0105$
$\alpha = -0.0118$	612.	.0129
$\beta = +0.0749$	399.	.0160

The $[nn.4]$ is $+161''.30$ and the probable error of a single observation is $\pm 0''.32$.

These values of x, α and β when substituted in the first normal equation resulting from the observation of each pair of stars furnish a value of Δ_0, the observed distance between the stars. A comparison of these observed distances with the computed distances $C—O$ of the following table will furnish the required test of the presence of systematic error. Such a comparison was made before definitive values for the star places had been derived and before the systematic difference C—F had been investigated. Since this comparison can be regarded as furnishing only provisional results I omit its details and present its general characteristics in the following table which

is constructed by arranging the differences $C—O$ in the order of magnitude of the quantity d and taking the means of groups of consecutive values.

REVISED COMPARISON OF THE OBSERVED AND COMPUTED DISTANCES.

Mean d	No. of Pairs.	Weight.	$C—O$	$C'—O'$
′			″	″
−7.0	9	10	+0.56	−0.52
−2.8	7	10	− .40	− .57
−0.3	7	10	− .58	− .58
+2.6	6	10	− .77	− .62
+5.2	7	11	−1.08	− .49

The weights are based upon the number of observations and upon the estimated precision of the adopted star places. No value of $C—O$ has been rejected in the formation of the tables.

The sequence shown by the values of $C—O$ could be in great part removed by altering the adopted value of a revolution of the micrometer screw and the column $C'—O'$ exhibits the results which would be obtained were this value diminished by 0″.07. But against the introduction of such a correction there is to be urged that it furnishes no explanation of the differences C—F, and that the adopted value of a revolution of the screw depends upon the accordant results furnished by two entirely independent methods which render the presence of so gross an error exceedingly improbable.

A comparison of the numbers $C—O$ with the numbers in the column C—F p. 152, noting that C and C in the two tables denote different quantities, suggests as a possible explanation of both series of discordances a fixed habit of observing on the part of C in accordance with which the micrometer threads were not placed upon the star images but a little farther apart than the images. Such a personal error may easily arise from the necessity experienced by the observer for turning his attention rapidly from one star to the other in estimating the coincidence of the micrometer threads with the images, since when d exceeds a fraction of a minute of arc both stars cannot be seen distinctly at the same moment. Since the effect of such an error is always to make d numerically too great its effect upon Δ will change sign when d passes through zero and the correction of —0″.07 to the value of a revolution of the micrometer screw above suggested might be regarded as arising from this source and as furnishing a measure of its effect. But if such is the origin of the discrepancies in question it appears to me probable that with increasing distances the errors will increase more rapidly than d, and I have therefore, somewhat arbitrarily, chosen to represent these errors as a function of the square of d, so that each observation by C

shall receive a correction of the form $\phi(d) = \pm b\,d^2$ where b is a constant to be determined from the observations and the upper sign is to be used for negative, the lower sign for positive values of d. A discussion of the data in the preceding table furnishes us an approximate value for b, 0".022, corresponding to one minute of arc as the unit in which d is to be expressed.

To obtain a definitive value for this correction term I have proceeded as follows: To each observation by C there was applied the corrections contained in the columns μ and τ of the Tabulated Results and a further correction of ± 0".022 d^2. The correction +0.002 R applied to the Δs in the first solution was omitted since the mean value of $C—O$ p. 151 indicates that the observed Δs when thus corrected are too great.

The mean value of Δ furnished by C's corrected observations of each pair of stars was then derived and compared with the value computed from definitive coordinates given upon subsequent pages. Each difference thus derived is the absolute term of an equation of the form

$$z + \left(\frac{d}{10}\right)^2 y = C - O$$

where y is one hundred times the correction to the assumed value of the coefficient —0".022 and z is the constant part of the difference $C—O$.

The following table shows the data from which these equations were formed:

DETERMINATON OF $\varphi(d)$ Obs'r C.

Pair.	d	No. of Obs.	$C—O$	v'	v''
	'		'	"	"
C (2)	−9.0	8	−0.08	+0.08	+1.83
A (3)	8.8	5	− .76	− .64	+ .55
F (2)	8.7	8	− .35	− .31	+ .95
C (1)	8.3	10	+ .41	+ .51	+1.56
D (1)	8.0	6	− .85	− .77	+ .19
B (1)	−7.9	9	+0.86	+0.93	+1.85
E (1)	4.7	9	− .04	− .16	+ .07
A (2)	4.5	17	+ .06	− .07	+ .13
VI	4.5	23	− .24	− .37	− .17
E (2)	4.2	7	+ .85	+ .71	+ .88
B (3)	−4.3	17	+0.50	+0.36	+0.53
III	4.2	14	+ .20	+ .06	+ .23
E (3)	3.5	27	+ .50	+ .38	+ .39
D (2)	3.0	9	− .02	− .20	− .19
VII	2.9	24	− .42	− .61	− .61

DETERMINATION OF $\varphi(d)$ — Continued.

Pair.	d	No. of Obs.	$C-O$	v'	v''
	′		′	″	″
F (1)	−2.4	17	+0.38	+0.18	+0.14
A (1)	1.4	10	+1.10	+ .89	+ .77
D (3)	1.3	15	+1.27	+1.06	+ .94
XII	1.2	16	+ .02	− .20	− .33
IX	0.4	24	+ .01	− .21	− .36
F (3)	−0.4	30	+0.04	−0.18	−0.33
XVIII	+0.3	2	+ .34	+ .12	− .03
B (2)	0.6	18	− .40	− .62	− .77
XIV	1.4	34	− .38	− .67	− .79
X	1.9	20	+ .49	+ .25	+ .03
XX	+2.3	27	+0.24	−0.01	−0.24
XVII	2.4	23	+ .42	+ .17	− .08
V	2.5	18	− .25	− .50	− .75
XI	3.5	1	+ .44	+ .16	− .19
VIII	3.8	26	− .36	− .65	−1.04
I	+4.1	8	+0.66	+0.36	−0.08
XXI	4.4	26	+ .56	+ .25	− .23
XV	4.7	37	+ .06	− .27	− .79
XIII	4.8	6	− .40	− .73	−1.28
IV	5.5	18	+ .83	+ .47	− .20
XIX	+5.8	15	+0.07	−0.81	−1.05
II	5.8	19	+1.08	+ .70	− .04
C (3)	6.1	15	+0.23	− .17	− .95

The equation furnished by each pair of stars was given unit weight except that in the two cases in which the number of observations of the pair was less than five, half weight was assigned.

The solution of these equations by the method of least squares furnished the values

$$x = +0''.223 \pm 0''.057 \qquad y = +0''.473 \pm 0''.174$$

whence

$$\varphi(d) = \pm\, b\, d^2 \qquad b = 0''.0173 \pm 0''.0017$$

The column v' of the preceding table gives the residuals furnished by the several pairs of stars after the introduction of the values of y and z above determined and the column v'' gives the residuals furnished by the same data when the systematic error represented by

$$\varphi(d) = \pm b\, d^2$$

is put equal to zero. A comparison of the sequence of signs in the respective columns as well as the comparison of the sums of the squares, $[vv] = 9''.24$, $[v'v'] = 19''.76$ leaves little room for doubt as to the reality of the error although its origin and the algebraic form of the correction required may well be different from that above suggested. The term $\phi(d)$ is therefore to be regarded as an empirical correction justified solely by the fact that it brings the measured distances into agreement with those computed from the coordinates of the stars.

In a private letter Dr. David Gill suggests that in case the ocular remained fixed in position during the observation instead of being moved from one star to the other as the bisections were made: "A *vera causa* for your term b would be found * * * * if there were parallax, *i. e.* the images of the stars not lying coincident with the plane of the wires. Now a coincidence of these planes is a subjective question in one sense — dependent on the part of the spectrum on which the eye most naturally focusses, so that for one observer the focus may be right for another not so." The ocular was fixed in position relative to the stars as is supposed in the above suggestion.

To determine the systematic error affecting the observations by F recourse may be had to the comparison C—F given on page 152. To each value of C—F given in the table I have applied the correction $\pm 0''.0173\, d^2$ to eliminate C's systematic error and obtain thus the column Δ—F where Δ differs from the true distance between the stars comprising a pair by a constant only. The numbers in this column show no systematic variation depending upon d and the magnitude of the fortuitous variations is not greater than should be expected from the character of the data upon which they are based. I therefore conclude that the observations by F are free from the systematic error represented by $\phi\,(d)$.

The column $\phi\,(d)$ of the table of results of observation contains the correction $\pm 0''.0173\, d^2$ computed for each observation with the actually measured value of d. In accordance with the conclusion drawn above this correction is put equal to zero for all observations by F.

Although Mr. Flint's observing appears to be free from the systematic error above discussed it will appear from an inspection of his individual results that they are peculiarly subject to large accidental errors and considerable doubt arises with regard to the manner in which they should be combined with the remainder of the work. I have finally decided to reject all observations by F which differ more than $1''$ from the mean of the corrected observations by C and to assign to each remaining observation a weight of one half.

No observation by C has been rejected or assigned other than unit weight save a few which were noted at the time of observation as being unsatisfactory or exposed to peculiar sources of error. This assignment of weights as between C and F corresponds very approximately to that which would be furnished by a consideration of the probable error of a single observation by the respective observers.

I have retained for the definitive discussion of the observations the form of equation introduced into the provisional discussion save that the assumed correction to the tabular refractions, $+0.002\,R$, is omitted, the provisional solution having shown that the correction is very nearly zero. I now put

$$\Delta_0 = D + w \qquad n = D - \Delta$$

where D is an assumed value of the true distance Δ_0, w, a correction to D to be determined from the observations, and n an absolute term derived by comparing each measured distance with the assumed D. The corresponding observation equation is

$$w + f x + A\alpha + B\beta + n = 0$$

The values of D, f, A, B and n, together with the weight, p, assigned to each equation are given upon the right hand pages of the Tabulated Results and from these equations there have been derived by the method of least squares the following normal equations for each pair of stars. The sum of the weighted squares of the absolute terms $[nn]$, and the value of w resulting from the finally adopted values of x, α and β are given in connection with the normal equations.

NORMAL EQUATIONS.

A (1). 16 Aquarii o Orionis.

$$\begin{array}{rrrrrl}
+12.75\,w & +13.65\,x & +17.14\,\alpha & -17.81\,\beta & +2''.05 = 0 & \\
+13.65\,w & +16.23\,x & +16.60\,\alpha & -20.89\,\beta & +0.84 = 0 & \\
+17.14\,w & +16.60\,x & +24.81\,\alpha & -22.00\,\beta & +4.08 = 0 & [nn] = 8''.82 \\
-17.81\,w & -20.89\,x & -22.00\,\alpha & +26.89\,\beta & -1.88 = 0 &
\end{array}$$

$$w = -0''.160 - 1.07x - 1.84\alpha + 1.40\beta = -0''.09$$

B(1). β Piscium 10 Monocerotis.

$$\begin{array}{rrrrrl}
+9.00\,w & -4.01\,x & +12.63\,\alpha & -2.61\,\beta & +2.29 = 0 & \\
-4.01\,w & +12.65\,x & -10.99\,\alpha & -10.89\,\beta & -4.49 = 0 & \\
+12.63\,w & -10.99\,x & +20.46\,\alpha & +1.99\,\beta & +5.15 = 0 & [nn] = 4.28 \\
-2.61\,w & -10.89\,x & +1.99\,\alpha & +13.06\,\beta & +2.94 = 0 &
\end{array}$$

$$w = -0''.254 + 0.45x - 1.40\alpha + 0.29\beta = -0''.18$$

C (1). *f* Piscium 23 Hydrae.

$$\begin{array}{rrrrrl}
+10.00\,w & -\ 7.45\,x & +11.85\,\alpha & -\ 4.31\,\beta & -\ 2.98 & = 0 \\
-\ 7.45\,w & +18.80\,x & -25.08\,\alpha & -\ 0.68\,\beta & +10.00 & = 0 \\
+11.85\,w & -25.08\,x & +34.08\,\alpha & -\ 0.55\,\beta & -12.98 & = 0 \\
-\ 4.31\,w & -\ 0.68\,x & -\ 0.55\,\alpha & +\ 3.42\,\beta & -\ 1.29 & = 0
\end{array}
\qquad [n\,n] = 6''.33$$

$$w = +\,0''.298 + 0.75\,x - 1.18\,\alpha + 0.48\,\beta = +\,0''.36$$

D (1). B.D.—0°, 258 ι Hydrae.

$$\begin{array}{rrrrrl}
+\ 6.00\,w & -\ 3.22\,x & -11.33\,\alpha & -\ 2.51\,\beta & +\ 3''.29 & = 0 \\
-\ 3.22\,w & +11.27\,x & -15.51\,\alpha & +\ 3.38\,\beta & -\ 4.64 & = 0 \\
+11.33\,w & -15.51\,x & +21.36\,\alpha & -\ 4.71\,\beta & +\ 6.25 & = 0 \\
-\ 2.51\,w & +\ 3.38\,x & -\ 4.71\,\alpha & +\ 1.17\,\beta & -\ 1.06 & = 0
\end{array}
\qquad [n\,n] = 4.40$$

$$w = -\,0''.548 + 1.37\,x - 1.39\,\alpha + 0.42\,\beta = -\,0''.45$$

I. α Piscium α Leonis.

$$\begin{array}{rrrrrl}
+\ 5.68\,w & -\ 1.53\,x & +\ 2.26\,\alpha & -\ 2.44\,\beta & -\ 0''.98 & = 0 \\
-\ 1.56\,w & +15.16\,x & -16.30\,\alpha & -\ 4.18\,\beta & -\ 3.87 & = 0 \\
+\ 2.26\,w & -16.30\,x & +17.64\,\alpha & +\ 4.00\,\beta & +\ 3.95 & = 0 \\
-\ 2.44\,w & -\ 4.18\,x & +\ 4.00\,\alpha & +\ 3.30\,\beta & +\ 2.08 & = 0
\end{array}
\qquad [n\,n] = 2.85$$

$$w = +\,0''.178 + 0.28\,x - 0.40\,\alpha + 0.48\,\beta = +\,0''.19$$

II. γ Ceti *l* Leonis.

$$\begin{array}{rrrrrl}
+19.00\,w & -\ 1.16\,x & +\ 1.92\,\alpha & -14.78\,\beta & +\ 4''.92 & = 0 \\
-\ 1.16\,w & +47.35\,x & -53.54\,\alpha & -\ 1.56\,\beta & -\ 2.77 & = 0 \\
+\ 1.92\,w & -53.54\,x & +60.63\,\alpha & +\ 1.08\,\beta & +\ 3.17 & = 0 \\
-14.78\,w & -\ 1.56\,x & +\ 1.08\,\alpha & +13.14\,\beta & -\ 2.88 & = 0
\end{array}
\qquad [n\,n] = 4.94$$

$$w = -\,0''.259 + 0.06\,x - 0.10\,\alpha + 0.78\,\beta = -\,0''.26$$

III. 32 Eridani 95 Leonis.

$$\begin{array}{rrrrrl}
+13.50\,w & +\ 0.72\,x & -\ 3.32\,\alpha & -10.65\,\beta & +\ 0''.45 & = 0 \\
+\ 0.72\,w & +31.78\,x & -36.49\,\alpha & +\ 4.66\,\beta & -\ 1.80 & = 0 \\
-\ 3.32\,w & -36.49\,x & +42.37\,\alpha & -\ 2.95\,\beta & +\ 1.84 & = 0 \\
-10.65\,w & +\ 4.66\,x & -\ 2.95\,\alpha & +11.45\,\beta & -\ 1.49 & = 0
\end{array}
\qquad [n\,n] = 2.64$$

$$w = -\,0''.033 - 0.05\,x + 0.25\,\alpha + 0.79\,\beta = -\,0''.06$$

E (1). α Ceti p^2 Leonis.

$$\begin{array}{rrrrrl}
+7.50\,w & +0.47\,x & -0.80\,\alpha & -5.81\,\beta & +2.75 & = 0 \\
+0.47\,w & +17.49\,x & -20.89\,\alpha & -1.15\,\beta & +1.61 & = 0 \\
-0.80\,w & -20.89\,x & +24.98\,\alpha & +1.50\,\beta & -2.06 & = 0 \\
-5.81\,w & -1.15\,x & +1.50\,\alpha & +4.19\,\beta & -1.63 & = 0
\end{array}$$

$[n\,n] = 8''.38$

$$w = -0''.366 - 0.06\,x + 0.11\,\alpha + 0.71\,\beta = -0''.38$$

F (1). 10 Tauri υ Leonis.

$$\begin{array}{rrrrrl}
+19.75\,w & +3.31\,x & -7.53\,\alpha & -15.28\,\beta & -1''.93 & = 0 \\
+3.31\,w & +42.25\,x & -51.52\,\alpha & +7.32\,\beta & -8.51 & = 0 \\
-7.53\,w & -51.52\,x & +63.49\,\alpha & -5.81\,\beta & +10.66 & = 0 \\
-15.28\,w & +7.32\,x & -5.81\,\alpha & +15.60\,\beta & -0.33 & = 0
\end{array}$$

$[n\,n] = 5.86$

$$w = +0''.098 - 0.17\,x + 0.38\,\alpha + 0.77\,\beta = +0''.07$$

IV. μ Tauri c Virginis.

$$\begin{array}{rrrrrl}
+18.50\,w & +10.69\,x & -17.39\,\alpha & -11.76\,\beta & -0''.60 & = 0 \\
+10.69\,w & +42.72\,x & -50.29\,\alpha & +5.82\,\beta & -5.43 & = 0 \\
-17.39\,w & -50.29\,x & +60.79\,\alpha & -2.36\,\beta & +5.61 & = 0 \\
-11.76\,w & +5.82\,x & -2.36\,\alpha & +13.32\,\beta & -2.86 & = 0
\end{array}$$

$[n\,n] = 3.76$

$$w = -0''.032 - 0.58\,x + 0.94\,\alpha + 0.64\,\beta = -0''.09$$

V. π^5 Orionis δ Virginis.

$$\begin{array}{rrrrrl}
+19.50\,w & +4.47\,x & -11.51\,\alpha & -9.63\,\beta & +3''.75 & = 0 \\
+4.47\,w & +48.54\,x & -53.16\,\alpha & +21.64\,\beta & -3.95 & = 0 \\
-11.51\,w & -53.16\,x & +60.64\,\alpha & -19.34\,\beta & +3.01 & = 0 \\
-9.63\,w & +21.64\,x & -19.34\,\alpha & +17.28\,\beta & -4.06 & = 0
\end{array}$$

$[n\,n] = 4.59$

$$w = -0''.192 - 0.23\,x + 0.59\,\alpha + 0.49\,\beta = -0''.23$$

A (2). ο Orionis B.D.+2°, 2664.

$$\begin{array}{rrrrrl}
+16.50\,w & +10.09\,x & -21.98\,\alpha & -9.18\,\beta & -7''.27 & = 0 \\
+10.09\,w & +27.71\,x & -36.32\,\alpha & +6.65\,\beta & -1.48 & = 0 \\
-21.98\,w & -36.32\,x & +53.85\,\alpha & -0.28\,\beta & +6.26 & = 0 \\
-9.18\,w & +6.65\,x & -0.28\,\alpha & +12.74\,\beta & +5.22 & = 0
\end{array}$$

$[n\,n] = 10.99$

$$w = +0''.441 - 0.61\,x + 1.33\,\alpha + 0.56\,\beta = +0.36$$

VI. θ Can. Maj. ϵ Bootis.

$$\begin{array}{rrrrrl}
+23.50\,w & -\ 2.49\,x & -\ 9.18\,\alpha & -12.27\,\beta & -\ 3''.21 & = 0 \\
-\ 2.49\,w & +56.91\,x & -55.19\,\alpha & +39.86\,\beta & +\ 3.39 & = 0 \\
-\ 9.18\,w & -55.19\,x & +60.59\,\alpha & -32.37\,\beta & -\ 1.78 & = 0 \\
-12.27\,w & +39.86\,x & -32.37\,\alpha & +33.62\,\beta & +\ 3.73 & = 0
\end{array} \qquad [n\,n] = 5''.33$$

$$w = +0''.137 + 0.11\,x + 0.39\,\alpha + 0.52\,\beta = +0''.11$$

VII. ϵ Tauri ϵ Corvi.

$$\begin{array}{rrrrrl}
+26.00\,w & +\ 4.12\,x & -11.02\,\alpha & -13.85\,\beta & +\ 6''.70 & = 0 \\
+\ 4.12\,w & +55.61\,x & -58.87\,\alpha & +37.96\,\beta & +\ 6.60 & = 0 \\
-11.02\,w & -58.87\,x & +64.52\,\alpha & -34.69\,\beta & -\ 8.85 & = 0 \\
-13.85\,w & +37.96\,x & -34.69\,\alpha & +39.56\,\beta & -\ 0.34 & = 0
\end{array} \qquad [n\,n] = 7.71$$

$$w = -0''.258 - 0.16\,x + 0.42\,\alpha + 0.53\,\beta = -0''.29$$

VIII. 119 Tauri α Virginis.

$$\begin{array}{rrrrrl}
+27.50\,w & +13.72\,x & -23.28\,\alpha & -\ 4.22\,\beta & +10''.70 & = 0 \\
+13.72\,w & +71.27\,x & -68.16\,\alpha & +46.52\,\beta & -\ 1.86 & = 0 \\
-23.28\,w & -68.16\,x & +70.27\,\alpha & -37.96\,\beta & -\ 2.29 & = 0 \\
-\ 4.22\,w & +46.52\,x & -37.96\,\alpha & +38.78\,\beta & -\ 6.58 & = 0
\end{array} \qquad [n\,n] = 10.40$$

$$w = -0''.389 - 0.50\,x + 0.84\,\alpha + 0.15\,\beta = -0''.44$$

B (2). 19 Monocerotis 110 Virginis.

$$\begin{array}{rrrrrl}
+18.50\,w & +\ 2.55\,x & -16.66\,\alpha & -\ 5.64\,\beta & +\ 2''.19 & = 0 \\
+\ 2.55\,w & +35.76\,x & -34.51\,\alpha & +29.35\,\beta & -\ 0.97 & = 0 \\
-16.66\,w & -34.51\,x & +46.13\,\alpha & -21.49\,\beta & -\ 0.44 & = 0 \\
-\ 5.64\,w & +29.35\,x & -21.49\,\alpha & +27.75\,\beta & -\ 1.58 & = 0
\end{array} \qquad [n\,n] = 1.58$$

$$w = -0''.118 - 0.14\,x + 0.90\,\alpha + 0.30\,\beta = -0''.17$$

IX. γ Geminorum 109 Virginis.

$$\begin{array}{rrrrrl}
+24.50\,w & +11.22\,x & -22.01\,\alpha & -\ 1.36\,\beta & +\ 1''.36 & = 0 \\
+11.22\,w & +58.99\,x & -55.44\,\alpha & +44.21\,\beta & -\ 0.52 & = 0 \\
-22.01\,w & -55.44\,x & +59.14\,\alpha & -35.66\,\beta & -\ 0.45 & = 0 \\
-\ 1.36\,w & +44.21\,x & -35.66\,\alpha & +38.00\,\beta & -\ 1.18 & = 0
\end{array} \qquad [n\,n] = 2.39$$

$$w = -0''.055 - 0.46\,x + 0.90\,\alpha + 0.06\,\beta = -0''.10$$

C (2). 23 Hydrae U Ophiuchi.

$$\begin{array}{rrrrrl} +7.50w & +8.75x & -9.82\alpha & +10.57\beta & +8''.32 = 0 & \\ +8.57w & +10.04x & -10.95\alpha & +12.34\beta & +9.31 = 0 & \\ -9.82w & -10.95x & +13.13\alpha & -13.56\beta & -11.03 = 0 & [nn] = 10''.76 \\ +10.57w & +12.34x & -13.56\alpha & +15.14\beta & +11.53 = 0 & \end{array}$$

$$w = -1''.109 - 1.14x + 1.31\alpha - 1.41\beta = -1''.17$$

D (2). ι Hydrae $Ll.$ 32200.

$$\begin{array}{rrrrrl} +10.00w & +11.80x & -11.45\alpha & +15.34\beta & +2''.60 = 0 & \\ +11.80w & +14.13x & -13.18\alpha & +18.26\beta & +2.64 = 0 & \\ -11.45w & -13.18x & +13.52\alpha & -17.28\beta & -3.57 = 0 & [nn] = 2.70 \\ +15.34w & +18.26x & -17.28\alpha & +23.64\beta & +3.64 = 0 & \end{array}$$

$$w = -0''.260 - 1.18x + 1.14\alpha - 1.53\beta = -0''.31$$

E (2). p^2 Leonis g Aquilae.

$$\begin{array}{rrrrrl} +9.50w & +9.32x & -7.11\alpha & +16.24\beta & +6''.26 = 0 & \\ +9.32w & +9.65x & -6.30\alpha & +16.16\beta & +5.75 = 0 & \\ -7.11w & -6.30x & +6.16\alpha & -11.81\beta & -5.17 = 0 & [nn] = 5.19 \\ +16.24w & +16.16x & -11.81\alpha & +27.79\beta & +10.47 = 0 & \end{array}$$

$$w = -0''.659 - 0.98x + 0.75\alpha - 1.71\beta = -0''.68$$

F (2). υ Leonis ι Aquilae.

$$\begin{array}{rrrrrl} +10.00w & +7.38x & -7.88\alpha & +16.89\beta & +12''.19 = 0 & \\ +7.38w & +6.10x & -4.98\alpha & +12.78\beta & +9.27 = 0 & \\ -7.88w & -4.98x & +7.22\alpha & -12.92\beta & -9.26 = 0 & [nn] = 16.12 \\ +16.89w & +12.78x & -12.92\alpha & +28.59\beta & +20.70 = 0 & \end{array}$$

$$w = -1''.219 - 0.74x + 0.79\alpha - 1.69\beta = -1''.25$$

A (3). B.D.$+2^{\circ}$,2664 16 Aquarii.

$$\begin{array}{rrrrrl} +7.50w & -7.77x & -13.01\alpha & +5.26\beta & +2''.90 = 0 & \\ -7.77w & +9.42x & +14.87\alpha & -4.42\beta & -3.07 = 0 & \\ -13.01w & +14.87x & +24.07\alpha & -8.35\beta & -5.14 = 0 & [nn] = 3.07 \\ +5.26w & -4.42x & -8.35\alpha & +5.02\beta & +2.10 = 0 & \end{array}$$

$$w = -0.387 + 1.04x + 1.74\alpha - 0.70\beta = -0''.48$$

X. μ Virginis ζ Pegasi.

$$\begin{aligned}
+23.50\,w - 2.46\,x - 5.16\,\alpha + 22.12\,\beta + 6''.12 &= 0 \\
- 2.46\,w + 38.66\,x + 49.40\,\alpha + 0.20\,\beta + 2.30 &= 0 \\
- 5.16\,w + 49.40\,x + 63.21\,\alpha - 1.73\,\beta + 2.38 &= 0 \\
+22.12\,w + 0.20\,x - 1.73\,\alpha + 23.66\,\beta + 6.87 &= 0
\end{aligned} \qquad [n\,n] = 5''.53$$

$$w = -0''.260 + 0.10\,x - 0.22\,\alpha - 0.94\,\beta = -0''.24$$

XII. 37 Librae 70 Pegasi.

$$\begin{aligned}
+16.75\,w + 4.34\,x + 7.94\,\alpha + 15.67\,\beta + 8''.02 &= 0 \\
+ 4.34\,w + 29.23\,x + 35.64\,\alpha - 3.39\,\beta + 9.35 &= 0 \\
+ 7.94\,w + 35.64\,x + 43.88\,\alpha - 1.34\,\beta + 12.49 &= 0 \\
+15.67\,w - 3.39\,x - 1.34\,\alpha + 17.15\,\beta + 5.62 &= 0
\end{aligned} \qquad [n\,n] = 7.92$$

$$w = -0''.479 - 0.26\,x - 0.47\,\alpha - 0.94\,\beta = -0''.44$$

XIII. β Librae γ Piscium.

$$\begin{aligned}
+ 9.00\,w - 5.22\,x - 5.53\,\alpha + 7.47\,\beta + 1''.68 &= 0 \\
- 5.22\,w + 20.01\,x + 23.17\,\alpha - 5.17\,\beta + 0.00 &= 0 \\
- 5.53\,w + 23.17\,x + 26.88\,\alpha - 5.51\,\beta + 0.07 &= 0 \\
+ 7.47\,w - 5.17\,x - 5.51\,\alpha + 7.01\,\beta + 0.87 &= 0
\end{aligned} \qquad [n\,n] = 2.48$$

$$w = -0''.187 + 0.58\,x + 0.61\,\alpha - 0.83\,\beta = -0''.22$$

B (3). 110 Virginis β Piscium.

$$\begin{aligned}
+20.25\,w + 7.93\,x + 10.64\,\alpha + 17.95\,\beta + 6''.81 &= 0 \\
+ 7.93\,w + 33.99\,x + 43.17\,\alpha - 1.44\,\beta + 3.03 &= 0 \\
+10.64\,w + 43.17\,x + 54.80\,\alpha - 1.19\,\beta + 3.98 &= 0 \\
+17.95\,w - 1.44\,x - 1.19\,\alpha + 19.03\,\beta + 6.05 &= 0
\end{aligned} \qquad [n\,n] = 7.15$$

$$w = -0''.336 - 0.39\,x - 0.52\,\alpha - 0.89\,\beta = -0''.30$$

XIV. 3 Serpentis ϕ Aquarii.

$$\begin{aligned}
+34.75\,w + 20.69\,x + 27.06\,\alpha + 26.06\,\beta + 14''.22 &= 0 \\
+20.69\,w + 64.98\,x + 77.34\,\alpha - 7.23\,\beta + 8.63 &= 0 \\
+27.06\,w + 77.34\,x + 92.30\,\alpha - 5.60\,\beta + 11.27 &= 0 \\
+26.06\,w - 7.23\,x - 5.60\,\alpha + 34.27\,\beta + 10.95 &= 0
\end{aligned} \qquad [n\,n] = 11.46$$

$$w = -0''.409 - 0.60\,x - 0.78\,\alpha - 0.75\,\beta = -0''.35$$

XV. δ Ophiuchi ι Ceti.

$$\begin{aligned}
+37.50\,w\ +33.95\,x + 44.94\,\alpha\ +11.97\,\beta\ - 2''.90 &= 0\\
+33.95\,w\ +85.54\,x + 94.50\,\alpha\ -22.98\,\beta\ - 8.41 &= 0\\
+44.94\,w\ +94.50\,x +107.29\,\alpha\ -16.88\,\beta\ - 9.25 &= 0\\
+11.97\,w\ -22.98\,x - 16.88\,\alpha\ +30.45\,\beta\ + 2.62 &= 0
\end{aligned}
\qquad [n\,n] = 8''.22$$

$$w = +0''.077 - 0.91\,x - 1.20\,\alpha - 0.32\,\beta = +0''.15$$

C (3). *U* Ophiuchi *f* Piscium.

$$\begin{aligned}
+14.50\,w\ +13.85\,x\ +24.98\,\alpha\ + 3.76\,\beta\ + 5''.75 &= 0\\
+13.85\,w\ +17.67\,x\ +26.70\,\alpha\ - 1.38\,\beta\ + 6.24 &= 0\\
+24.98\,w\ +26.70\,x\ +45.19\,\alpha\ + 3.76\,\beta\ +11.04 &= 0\\
+ 3.76\,w\ - 1.38\,x\ + 3.76\,\alpha\ + 7.14\,\beta\ + 1.53 &= 0
\end{aligned}
\qquad [n\,n] = 5.64$$

$$w = -0''.397 - 0.96\,x - 1.72\,\alpha - 0.26\,\beta = -0''.29$$

XVII. B.A.C. 5903 μ Piscium.

$$\begin{aligned}
+25.83\,w\ +13.13\,x\ +27.13\,\alpha\ - 1.36\,\beta\ - 5''.33 &= 0\\
+16.13\,w\ +53.89\,x\ +46.56\,\alpha\ -45.93\,\beta\ - 2.19 &= 0\\
+27.13\,w\ +46.56\,x\ +49.47\,\alpha\ -30.78\,\beta\ - 5.54 &= 0\\
- 1.36\,w\ -45.93\,x\ -30.78\,\alpha\ +47.64\,\beta\ - 1.82 &= 0
\end{aligned}
\qquad [n\,n] = 9.26$$

$$w = +0''.206 - 0.62\,x - 1.05\,\alpha + 0.05\,\beta = +0''.27$$

XVIII. B.A.C. 5647 17 Ceti.

$$w = +0.045 + 0.76\,x - 0.10\,\alpha - 1.84\,\beta = +0.06$$

D (3). Ll. 32200 B.D.—0°, 258

$$\begin{aligned}
+13.75\,w\ + 6.73\,x\ +18.53\,\alpha\ + 7.72\,\beta\ + 0''.05 &= 0\\
+ 6.73\,w\ +14.57\,x\ +15.78\,\alpha\ - 8.08\,\beta\ - 1.84 &= 0\\
+18.53\,w\ +15.78\,x\ +30.47\,\alpha\ + 5.08\,\beta\ - 1.35 &= 0\\
+ 7.72\,w\ - 8.08\,x\ + 5.08\,\alpha\ +18.83\,\beta\ + 1.98 &= 0
\end{aligned}
\qquad [n\,n] = 5.80$$

$$w = -0''.004 - 0.49\,x - 1.35\,\alpha - 0.56\,\beta = +0''.08$$

XIX. ι Coronae A² Aquarii.

$$\begin{aligned}
+15.00\,w\ +13.25\,x\ +17.96\,\alpha\ - 2.96\,\beta\ - 0''.79 &= 0\\
+13.25\,w\ +25.53\,x\ +27.82\,\alpha\ -20.06\,\beta\ + 0.04 &= 0\\
+17.96\,w\ +27.82\,x\ +32.08\,\alpha\ -17.89\,\beta\ - 0.17 &= 0\\
- 2.96\,w\ -20.06\,x\ -17.89\,\alpha\ +24.53\,\beta\ - 0.28 &= 0
\end{aligned}
\qquad [n\,n] = 3.49$$

$$w = +0''.053 - 0.88\,x - 1.20\,\alpha + 0.20\,\beta = +0''.12$$

XX. 5 H Scuti γ Ceti.

$$
\begin{array}{rrrrrl}
+29.00\,w & -\ 1.60\,x & +19.61\,\alpha & +12.40\,\beta & +2''.79 & = 0 \\
-\ 1.60\,w & +64.92\,x & +26.31\,\alpha & -70.26\,\beta & +\ 6.27 & = 0 \\
+19.61\,w & +26.31\,x & +26.20\,\alpha & -20.10\,\beta & +\ 4.69 & = 0 \\
+12.40\,w & -70.26\,x & -20.10\,\alpha & +80.67\,\beta & -\ 5.59 & = 0
\end{array}
\qquad [n\,n] = 6''.22
$$

$$w = -\,0''.096 + 0.06\,x - 0.68\,\alpha - 0.43\,\beta = -0''.05$$

E (3). *g* Aquilae. α Ceti.

$$
\begin{array}{rrrrrl}
+32.00\,w & +\ 7.31\,x & +36.55\,\alpha & +\ 6.95\,\beta & +12''.23 & = 0 \\
+\ 7.31\,w & +53.51\,x & +31.60\,\alpha & -52.44\,\beta & +\ 9.19 & = 0 \\
+36.55\,w & +31.60\,x & +58.01\,\alpha & -13.06\,\beta & +20.47 & = 0 \\
+\ 6.95\,w & -52.44\,x & -13.06\,\alpha & +59.54\,\beta & -\ 2.11 & = 0
\end{array}
\qquad [n\,n] = 17.41
$$

$$w = -\,0''.382 - 0.23\,x - 1.14\,\alpha - 0.22\,\beta = -0''.31$$

XXI. ν Aquilae *f* Tauri.

$$
\begin{array}{rrrrrl}
+28.00\,w & +\ 9.86\,x & +20.89\,\alpha & -\ 8.33\,\beta & -\ 4''.99 & = 0 \\
+\ 9.86\,w & +65.85\,x & +23.32\,\alpha & -74.53\,\beta & -\ 2.81 & = 0 \\
+20.89\,w & +23.32\,x & +22.69\,\alpha & -23.51\,\beta & -\ 3.12 & = 0 \\
-\ 8.33\,w & -74.53\,x & -23.51\,\alpha & +84.96\,\beta & +\ 2.95 & = 0
\end{array}
\qquad [n\,n] = 5.89
$$

$$w = +\,0''.178 - 0.35\,x - 0.75\,\alpha + 0.30\,\beta = +\,0''.22$$

F (3). ι Aquilae 10 Tauri.

$$
\begin{array}{rrrrrl}
+34.00\,w & +21.74\,x & +37.32\,\alpha & -15.72\,\beta & -\ 0''.38 & = 0 \\
+21.74\,w & +68.30\,x & +35.53\,\alpha & -71.19\,\beta & +\ 2.38 & = 0 \\
+37.32\,w & +35.53\,x & +53.53\,\alpha & -26.56\,\beta & +\ 1.53 & = 0 \\
-15.72\,w & -71.19\,x & -26.56\,\alpha & +77.30\,\beta & -\ 2.22 & = 0
\end{array}
\qquad [n\,n] = 7.07
$$

$$w = +\,0''.011 - 0.64\,x - 1.10\,\alpha + 0.46\,\beta = +0''.07$$

Since w is the only unknown quantity whose value differs in the equations corresponding to the several pairs of stars I have made this the first quantity to be eliminated and have placed in the following table the coefficients and absolute terms, etc., [*bb*.1], [*bc*.1], [*cn*.1], [*sn*.1], resulting from the several eliminations. A summation of the quantities standing in the same column will furnish a final set of normal equations for the determination of the three unknowns, x, α and β.

Pair.	Obs.	[bb.1]	[bc.1]	[bd.1]	[bn.1]	[bs.1]	[cc.1]	[cd.1]
* A (1)	16	1.62	− 1.75	− 1.82	− 1.36	− 3.32	+ 1.77	+ 1.94
* B (1)	10	10.86	− 5.86	−11.55	− 3.47	− 9.52	+ 2.73	+ 5.65
* C (1)	10	13.25	−16.25	− 3.89	+ 7.78	+ 0.89	+20.04	+ 4.56
* D (1)	7	0.01	+ 0.01	− 0.06	− 0.18	− 0.17	− 0.03	+ 0.03
I	12	14.73	−15.68	− 4.85	− 4.14	− 9.94	+16.74	+ 4.97
II	21	47.28	−53.42	− 2.46	− 2.47	−11.07	+60.44	+ 2.57
III	14	31.74	−36.31	+ 5.23	− 1.82	− 1.16	+41.55	− 5.57
* E (1)	7	17.46	−20.84	− 0.82	+ 1.44	− 2.75	+24.89	+ 0.93
F (1)	23	41.70	−50.26	+ 9.88	− 8.19	− 6.87	+60.62	−11.64
IV	19	36.54	−40.24	+12.62	− 5.78	+ 3.14	+44.44	−13.41
V	21	47.52	−50.52	+23.85	− 4.81	+16.00	+58.84	−25.03
* A (2)	17	21.54	−22.88	+12.26	+ 2.97	+13.89	+24.58	−12.51
VI	27	56 65	−56.16	+38.56	+ 3.05	+42.19	+57.00	−37.16
VII	29	54.96	−57.12	+40.16	+ 5.54	+43.54	+59.85	−40.57
VIII	31	64.43	−56.57	+48.63	− 7.20	+49.29	+50.74	−41.53
B (2)	20	35.41	−32.21	+30.13	− 1.27	+32.06	+31.13	−26.57
IX	26	53.85	−45.36	+44.83	− 1.14	+52.19	+39.38	−36.88
* C (2)	8	0.25	+ 0.27	+ 0.26	− 0.17	+ 0.61	+ 0.27	+ 0.28
* D (2)	11	0.20	+ 0.33	+ 0.16	− 0.43	+ 0.26	+ 0.41	+ 0.28
* E (2)	12	0.51	+ 0.68	+ 0.23	− 0.39	+ 1.03	+ 0.84	+ 0.35
* F (2)	12	0.65	+ 0.84	+ 0.32	+ 0.27	+ 2.08	+ 1.01	+ 0.38
* A (3)	10	1.37	+ 1.39	+ 1.07	− 0.07	+ 3.78	+ 1.51	+ 0.77
X	27	38.40	+48.86	+ 2.50	+ 2.94	+92.72	+62.08	+ 3.13
XII	19	28.11	+33.58	− 7.45	+ 7.27	+61.51	+40.12	− 8.77
* XIII	13	16.98	+19.96	− 0.84	+ 0.97	+37.07	+23.48	− 0.92

[cn.1]	[cs.1]	[dd.1]	[dn.1]	[ds.1]	[nn.1]	[sn.1]	Pair.
+1.32	+ 3.28	2.01	+1.48	+ 3.61	3.49	+ 4.93	A (1)
+1.93	+ 4.95	12.30	+3.60	+10.00	3.70	+ 5.76	B (1)
−9.40	− 1.05	1.56	−2.57	− 0.34	5.44	+ 1.25	C (1)
+0.04	+ 0.05	0.12	+0.32	+ 0.41	2.60	+ 2.83	D (1)
+4.34	+10.37	2.25	+1.61	+ 3.98	2.18	+ 3.99	I
+2.67	+12.26	1.64	+0.95	+ 2.70	3.66	+ 4.81	II
+1.95	+ 1.62	3.05	−1.13	+ 1.58	2.62	+ 1.62	III
−1.77	+ 3.20	0.43	+0.82	+ 0.88	7.37	+ 7.36	E (1)
+9.93	+ 8.64	3.78	−1.82	+ 0.18	5.67	+ 5.58	F (1)
+6.17	− 3.04	5.84	−2.48	+ 2.57	3.74	+ 1.65	IV
+5.22	−16.49	12.52	−2.21	+ 9.13	3.87	+ 2.07	V
−3.42	−14.23	7.63	+1.18	+ 8.56	7.79	+ 8.52	A (2)
−8.03	−39.35	27.21	+2.05	+30.66	4.89	+ 6.96	VI
−6.01	−43.85	32.18	+3.23	+35.01	5.98	+ 8.74	VII
+6.75	−40.61	38.13	−4.94	+40.29	6.24	+ 0.85	VIII
+1.53	−26.12	26.03	−0.91	+28.68	1.32	+ 0.67	B (2)
+0.77	−42.09	37.92	−1.05	+44.83	2.29	+ 0.87	IX
−0.14	+ 0.68	0.24	−0.19	+ 0.60	1.53	+ 1.03	C (2)
−0.59	+ 0.43	0.11	−0.35	+ 0.21	2.02	+ 0.65	D (2)
−0.48	+ 1 38	0.02	−0.23	+ 0.38	1.06	− 0.04	E (2)
+0.34	+ 2.57	0.05	+0.11	+ 0.86	1.26	+ 1.98	F (2)
−0.11	+ 3.56	1.31	+0.07	+ 3.24	1 95	+ 1.84	A (3)
+3.72	+117.78	2.84	+0.61	+ 9.08	3.94	+11.21	X
+3.69	+73.62	2.49	−1.88	−15.61	4.08	+18.16	XII
+1.10	+43.62	0.81	−0.52	− 1.47	2.17	+ 3.72	XIII

Pair.	Obs.	[bb.1]	[bc.1]	[bd.1]	[bn.1]	[bs.1]	[c c.1]	[cd.1]
B (3)	23	30.87	+39.00	− 8.47	+0.36	+61.76	49.21	−10.62
XIV	43	52.66	+61.22	−22.75	+0.16	+91.29	71.22	−25.90
XV	46	54.79	+53.81	−33.82	−5.78	+69.02	53.44	−31.23
* C (3)	15	4.44	+ 2.84	− 4.97	+0.75	+ 3.06	2.16	− 2.72
XVII	30	43.82	+29.63	−45.08	+1.14	+29.50	20.97	−29.35
* D (3)	16	11.28	+ 6.71	−11.86	−1.86	+ 4.27	5.49	− 5.32
* XIX	18	18.82	+11.95	−17.44	+0.74	+ 9.07	10.58	−14.35
XX	32	64.83	+27.39	−69.58	+6.42	+29.06	12.94	−28.49
E (3)	36	51.84	+23.25	−54.03	+6.40	+27.46	16.26	−21.00
XXI	32	62.38	+15.96	−71.60	−1.05	+ 5.69	7.11	−17.30
F (3)	39	54.40	+11.67	−61.14	+2.62	+ 7.55	12.58	− 9.30

[cn.1]	[cs.1]	[dd.1]	[dn.1]	[ds.1	[nn.1]	[sn.1]	Pair.
+0.40	+ 77.96	3.12	+0.02	−16.00	4.86	+ 5.64	B (3)
+0.19	+106.73	14.73	+0.29	−33.63	5.64	+ 6.28	XIV
−5.77	+ 70.25	26.63	+3.54	−34.88	8.00	− 0.01	XV
+1.13	+ 3.41	6.16	+0.04	− 1.49	3.36	+ 5.30	C (3)
+0.06	+ 21.30	47.57	−2.10	−28.97	8.16	+ 7.26	XVII
−1.42	+ 5.46	14.50	+1.95	− 0.73	5.80	+ 4.47	D (3)
+0.77	+ 8.95	23.95	−0.39	− 8.23	3.45	+ 4.57	XIX
+2.80	+ 14.64	75.37	−6.78	−29.48	5.95	+ 8.42	XX
+6.51	+ 25.01	58.03	−4.77	−21.77	12.74	+20.38	E (3)
+0.60	+ 6.37	82.48	+1.47	− 4.95	5.00	+ 6.02	XXI
+1.95	+ 16.89	70.03	−2.40	− 2.81	7.07	+ 9.24	F (3)

From the summation of the preceding reduced normals furnished by each pair of stars I obtain the following normal equations designated as Solution II:

SOLUTION II. NORMAL EQUATIONS.

$$\begin{aligned}
1078.91\,x \quad -168.74\,\alpha \quad -163.59\,\beta \quad - 0.55 &= 0 \\
-168.74\,x \quad +977.95\,\alpha \quad -430.58\,\beta \quad +87.81 &= 0 \qquad [nn.1] = 157''.02 \\
-163.59\,x \quad -430.58\,\alpha \quad +645.02\,\beta \quad -13.83 &= 0
\end{aligned}$$

The solution of these equations furnishes the following values of the unknown quantities, together with their weights and probable errors, the latter quantities being derived from $[nn.4] = 155''.49$, which gives as the probable error of a single observation $r_1 = \pm 0''.315$.

Unknowns.	Weight.	Prob. Error.
$x = -0''.0081$	924	$\pm 0''.0104$
$\alpha = -0.0446$	615	± 0.0127
$\beta = -0.0104$	401	± 0.0157

This solution does not appear to me the best result which can be derived from the data in hand. Each unknown quantity is the coefficient of a term whose period is a year, and it is evident that no series of observations extending over only a small fraction of a year or limited to the same portion of different years can contribute much to this determination.

The presence of such limited and undesirable series of observations will be indicated in the table pp. 166, 168 by small values of the quadratic coefficients $[bb.1]$, $[cc.1]$, $[dd.1]$, and I have therefore formed a new set of normal equations by rejecting from the table every equation in which $[bb.1]$ is less than 25. This limit, although somewhat arbitrarily assumed, corresponds to a real difference in the character and quality of the observations, the rejected pairs being for the most part refraction stars. These occupied a subordinate place in the observing programme and were observed at such times as would least conflict with the observation of the aberration stars. The average number of micrometer settings contained in an observation of a refraction pair is less than two-thirds of the corresponding number for an aberration pair and the settings were at times hastily made in order to complete the observation in time for a closely following aberration pair.

A certain number of pairs of stars entering into the triplets of the refraction observing list were observed as aberration pairs and are directly comparable with the other aberration stars in quality as well as in the magnitude of the coefficients which they furnish. These pairs are retained in the following group of normal equations formed by the application of the criterion $[bb.1] > 25$.

SOLUTION III. NORMAL EQUATIONS

$$
\begin{array}{rrrrl}
952.28\,x & -133.81\,\alpha & -119.99\,\beta & -\ 8.61 & = 0 \\
-133.81\,x & +844.92\,\alpha & -414.62\,\beta & +45.09 & = 0 \\
-119.99\,x & -414.62\,\alpha & +571.59\,\beta & -20.31 & = 0
\end{array}
\qquad [nn.1] = 105.70
$$

The elimination equations resulting from these normals are

$$
\begin{array}{r}
x + 0.140\,\alpha - 0.126\,\beta - 0''.0038 = 0 \\
\alpha - 0.522\,\beta + 0.0539 = 0 \\
\beta + 0.0076 = 0
\end{array}
$$

The values of the unknowns together with their weights and probable errors derived from

$$[nn.4] = 103''.83 \qquad r_1 = \pm 0''.296$$

are

Unknowns	Weight	Prob. Error
$x = -0''.0053$	838	$\pm 0''.0102$
$\alpha = -0.0579$	491	± 0.0134
$\beta = -0.0076$	331	± 0.0163

The small values derived for α and β show that the refraction tables very closely represent the seasonal changes in the amount of the refration and it is perhaps doubtful if these results should be considered as indicating any real deviation from the tables. It does not seem permissible, however, to put equal to zero a quantity which is more than four times as great as the probable error of its determination and I therefore retain both α and β in the value of x, noting only that if they were rejected the resulting constant of aberration would be increased by $0''.009$. Passing from α and β to the factor by which they were introduced into the expression for the refraction we obtain

$$R = R_0\,[\,1 + 0.00058 \sin\,(2\,\pi\,t + 188^\circ)\,]$$

an expression which may be construed either as indicating that the true refraction attains its maximum excess over the tabular refraction about the autumnal equinox and its maximum defect about the vernal equinox, or as arising from some periodic change in the instrument or observer. For a star in 45° zenith distance the maximum seasonal deviation of the true from the tabular refraction in zenith distance would be only $0''.03$.

The assumed value of the constant of aberration with which the observations were reduced is $k = 20''.4481$ and applying to this the values of x found in the several solutions there result the following determinations of this constant:

Solution I	$k = 20''.499$	$\pm 0''.0105$
II	20.440	± 0.0104
III	20.443	± 0.0103

The values given by Solutions II and III are substantially the same but they differ considerably from the result of Solution I and it is a singular coincidence that this difference corresponds very closely to the difference in the values of the constant derived by Struve and Nyrén. I have published, Astr. Jour. No. 261, the results of a provisional discussion of a portion of the observations, which furnished the value $k = 20''.494 \pm 0''.017$. This result is comparable with the result of Solution I since the observations are treated by methods not fundamentally different and the numerical difference in the results is not greater than might be anticipated from the increased amount of data and elaborateness of discussion contained in Solution I. The diminution in the value of k shown in Solutions II and III is due to the introduction of the systematic correction $\phi(d)$ to my observations. That such a correction is required does not seem to me to admit of doubt, but it has been above shown that a different algebraic form, a correction to the value of a revolution of the micrometer, might be given to this correction which would satisfy the observed data nearly if not quite as well as that actually adopted.

Algebraically a correction to the value of a revolution of the micrometer screw is equivalent to the assumption

$$\varphi(d) = ad \qquad a = -0''.07$$

and the effect of such a correction upon the constant of aberration would be to diminish it in the ratio $(27''.417 - 0''.07) : 27''.417$. If this correction were applied to all of the observations it would furnish for k the value $20''.4467$, but since observations by F have been shown not to require such a correction the difference between this value and that furnished by Solution I, $0''.052$, should be diminished in the ratio $C : C+F$ where C and F represent the total weights attributed to the observations of Observers C and F. This ratio is very approximately $583 : 652$ and the resulting value of the constant of aberration is $k = 20''.452$, in substantial agreement with the results of Solutions I and II.

Other algebraic forms for the function $\phi(d)$ may easily be suggested but any plausible hypothesis with regard to the character of the systematic error in the observations by C must lead to a value of k not sensibly different from Struve's result.

To illustrate the measure of agreement *inter se* of the values of k I have prepared the following table which exhibits the value resulting from each pair of stars included in Solution III, i. e. each pair for which $[bb.1]$ exceeds 25. The quantity x^1 is the correction to the assumed constant of aberration which would be furnished if the seasonal variation of the refraction were assumed to be insensible. The column $a\,\beta$ shows the effect of this variation upon the value of k, and $x = x^1 + a\,\beta$ is the value of the correction when the variation is taken into account. The introduction of these terms does not change the mean value of k, by so much as $0''.01$, but it considerably diminishes the residuals and eliminates the systematic character of the sequence of signs shown in the column x^1:

Pair.	[bb.1]	x^1	$\alpha\beta$	x	d
		″	″	″	′
II	47.3	+0.05	−0.07	−0.02	+5.8
III	31.7	+ .06	− .07	− .01	−4.2
F (1)	41.7	+ .20	− .07	+ .13	−2.4
IV	36.5	+ .16	− .06	+ .10	+5.5
V	47.5	+ .10	− .06	+ .04	+2.5
VI	56.6	− .05	− .05	− .10	−4.5
VII	55.0	− .10	− .05	− .15	−2.9
VIII	64.4	+ .11	− .04	+ .07	+3.9
B (2)	35.4	+ .04	− .05	− .01	+0.6
IX	53.8	+ .02	− .04	− .02	−0.4
X	38.4	− .08	+ .07	− .01	+1.9
XII	28.1	− .26	+ .07	− .19	−1.3
B (3)	30.9	− .01	+ .07	+ .06	−4.2
XIV	52.7	− .00	+ .06	+ .06	+1.4
XV	54.8	+ .10	+ .05	+ .15	+4.6
XVII	43.8	− .03	+ .03	.00	+2.4
XX	64.8	− .10	+ .02	− .08	+2.3
E (3)	51.8	− .12	+ .02	− .10	−3.5
XXI	62.4	+ .02	+ .01	+ .03	+4.4
F (3)	54.4	− .05	+ .01	− .04	−0.5

It remains to show that the values of x are still affected with minute systematic errors for whose origin I am unable to assign a probable cause. The last column of the preceding table gives the mean value of d, the measured micrometer distance. If the values of x be arranged in the order of magnitude of d and the means of consecutive groups of five pairs be taken we shall obtain the results shown in the following table:

Mean d	x
′	″
−3.9	−0″.063
−0.8	− .029
+2.1	+ .005
+4.8	+ .066

Although these quantities are small there appears to be a well marked sequence in their values which is fairly represented by the formula

$$x = -0''.010 + 0''.014\,d$$

It may readily be shown that such a relation would result from an error of measurement depending upon the square of d, *e. g.* the application to all the observations of the correction

$$\varphi(d) = -0''.007\,d^2$$

would remove the sequence in the values of x without introducing intolerable errors into the measurements of absolute distance, Δ. The correction, however, does not appear to me sufficiently well established to warrant its application to the observations, but we may note that if it be considered real its effect vanishes when $d = 0$ and since the mean value of d in the twenty pairs of stars contained in Solution III is only $+0'.5$ its effect upon the resulting value of the constant of aberration will be evanescent.

It should be noted that the uncertainty with regard to the algebraic form which should be assigned to the systematic corrections which have been represented by $\phi(d)$ does not seriously affect the resulting value of the constant of aberration. All of the resulting values cluster about the result given by Solution III and differ from it by amounts little if at all exceeding its probable error. This might have been anticipated since each of the hypotheses suffices to bring the measured and computed values of Δ into agreement. I therefore adopt as the definitive result of the present investigation of the aberration the value given by Solution III:

CONSTANT OF ABERRATION $= 20''.443 \pm 0''.010.$

ADOPTED COORDINATES OF THE STARS.

Since the investigation of the refraction is based in part upon a comparison of the observed and computed values of Δ for the several pairs of stars it will be expedient to consider at this point the sources from which I have derived the adopted coordinates (α, δ) upon which the computed distances depend. As a basis for these coordinates I have adopted the system of Auwers, *Fundamental Catalog für die Zonen Beobachtungen am Nördlichen Himmel. Leipzig, 1879;* and I have divided the accessible data for the formation of star places into five classes, viz.:

A. Ephemerides and modern catalogues compiled from original sources. *B.* Original catalogues from the first half of the present century. *C.* The more important original catalogues from the second half of the present century. *D.* Original catalogues from the second half of the present century which are either of inferior precision or of limited extent. *E.* The results of a determination of the relative right ascensions of most of the stars observed with the prism apparatus, made with the

meridian circle of the Washburn Observatory by Mr. A. S. Flint, during the years 1892-'93, and published in Part 2 of this volume.

In the following statement of the sources employed the several catalogues are designated either by well known titles or by the name of the author, with place and date of publication. In the case of all catalogues except Nos. 1, 2, 11, 12, 13, 18, 19, 29, systematic corrections have been applied to reduce the catalogue positions to those of the adopted system of star places. Wherever possible these corrections have been derived from published comparisons of the catalogue in question with the standard system of star places. When no such comparison was available I have myself made a sufficient comparison for the purpose in hand.

The extensive reduction tables published by Dr. Auwers in No. 3195-96 of the *Astronomische Nachrichten* were not received until after the completion of the present investigation, but I have compared with them the systematic corrections employed in the derivation of the adopted star places and find that while there are numerous discrepancies between the numbers which I have employed and those given in the tables, yet upon the whole the agreement is such that I am convinced that no substantial improvement in the star places would be produced by introducing these new values.

AUTHORITIES FOR THE STAR PLACES.

Class A.

(1) 303 ** Vorläufiger Fundamental Catalog für die Südlichen Zonen. Auwers.
(2) B. J. Berliner Astronomisches Jahrbuch.
(3) A. E. American Ephemeris.
(4) Nb. Catalogue of 1098 Standard Clock and Zodiacal Stars. Newcomb.
(5) Bs. Declinations of Fixed Stars. Boss.

Class B.

(6) Pd. A Catalogue of 1112 Stars. Pond.
(7) P. M. Stellarum Fixarum Positiones Mediae. Struve.
(8) Abo. DLX Stellarum Fixarum Positiones Mediae. Argelander.
(9) Ah. Places of 5345 Stars Observed * * * at the Armagh Observatory. Robinson.
(10) Eh. Astronomical Observations made at the Royal Observatory, Edinburgh. Henderson.

Class C.

(11) P. The Pulkowa fundamental catalogues.
(12) P.M.C. Positions Moyennes de 3542 Étoiles. Pulkowa.
(13) Romb. Catalog von 5634 Sternen. Romberg.
(14) Gr. (date). The several Greenwich catalogues and recent annual volumes.

(15) Rog. Catalogue of 1213 Stars. Rogers.
(16) Cape. Catalogue of 12441 Stars. Cape of Good Hope. Stone.
(17) Cb. Catalogo General Argentino. Cordoba. Gould.
(18) Bk. Resultate aus Beobachtungen von 521 Bradley'schen Sternen. Becker.
(19) Hfk. Catalogue d' Étoiles Lunaires. Hilfiker.
(20) Rgh. Catalogi delle Declinazioni Medie. Respighi.

CLASS D.

(21) Sj. Stjernefortegnelse. Schellerup.
(22) C. B. Mittlere Oerter. Copeland and Börgen, Göttingen, 1869.
(23) Mh. Erstes Münchener Sternverzeichniss. Seeliger, Bauschinger.
(24) Ps. Catalogue de l' Observatoire de Paris. Tome I.
(25) Gw. Catalogue of Stars Observed at the Glasgow Observatory from 1860 to 1881.
(26) Ah. II. Second Armagh Catalogue of 3300 Stars.
(27) Krh. Veröffentlichungen der Grossherzoglichen Sternwarte zu Karlsruhe. Viertes Heft.
(28) Bx. Catalogue de 10792 Étoiles observées à l' Observatoire Royal de Bruxelles. Quetelet.

CLASS E.

(29) F. Publications Washburn Observatory. Vol. IX. Part 2. Flint.

In combining the data contained in the above authorities I have first obtained proper motions from some one of the sources 1, 2, 12, 13, 4, the sequence of the numbers indicating the order of preference. In case satisfactory proper motions could not be obtained from the catalogues I have derived them from a discussion of all of the data, usually employing graphical methods. The catalogues of Class B have been used solely for such determinations of proper motions.

Whenever the position of a star is given in either of the authorities 1, 2, 3, the position there given, or first given in case it occurs in more than one of them, is combined with the position given in 29 and the result adopted as the definitive place of the star. For those stars whose coordinates are not given in either 1, 2 or 3, I have derived values from a discussion of all the data furnished by Classes B, C and E, save that I have rarely employed the earlier Greenwich catalogues when the place of a star is contained in the Nine or Ten Year Cata'ogue. For stars whose places can not be obtained from more than one of the authorities of Classes B and C, I have had recourse to the catalogues of Class D.

The data upon which the adopted places rest are set forth in the following table. It should be noted that the systematic corrections included in the following exhibit are those of *Astr. Nachr.* No. 3195-'96 and not those actually employed in deriving the adopted places

The printed mean values which are adopted for the computation of the Δs are therefore not the best values which could be obtained from the printed data, but it may be seen that they differ from these best values by insignificant amounts.

A number in ( ) placed after the seconds of R. A. or Dec. denotes the number of observations upon which the place depends.

COORDINATES OF THE STARS FOR 1890.0.

ι Ceti.

$0^h\ 13^m$, $-9^\circ\ 26'$

$\mu = -0^s.0032$ $\mu' = -0''.032$

B. J.	$49^s.373$	$2''.11$
F.	.381 (11)	....
	49.380	2.11

17 Ceti.

$0^h\ 38^m$, $-11^\circ\ 12'$

$\mu = -0^s.0027$ $\mu' = -0''.113$

P.M.C.	$38^s.46$ (4)	$31''.8$ (4)
Cape	.48 (3)	31.9 (3)
Cb.	.44 (3)	33.0 (3)
Gr. 80	.47 (3)	31.9 (3)
	38.456	32.30

f Piscium.

$1^h\ 12^m$ $+3^\circ\ 2'$

$\mu = -0^s.0049$ $\mu' = -0''.019$

P.M C.	$7^s.48$ (4)	$5''.7$ (4)
Nb.	7.46 (39)	6.5 (50)
Gr. 80	7.51 (3)	5.1 (3)
Hfk.	7.46 (15)	....
F.	7.45 (12)	...
	7.464	5.64

μ Piscium.

$1^h\ 24^m$, $+5^\circ\ 34'$

$\mu = +0^s.0180$ $\mu' = -0''.037$

Nb.	$25^s.22$ (63)	$36''.0$ (63)
Gr. 72	.21 (19)	36.0 (20)
Romb.	.29 (5)	35.3 (5)
Gr. 80	.31 (3)	35.6 (4)
Hfk.	.25 (12)	....
F.	.28 (12)	...
	25.285	35.82

B. D.—0°, 258.

$1^h\ 34^m$, $-0^\circ\ 48'$

$\mu = +0^s.0019$ $\mu' = 0''.000$

Mb.	$29^s.42$ (3)	$2''.0$ (3)
Ps.	.39 (3)	0.8 (3)
C. B.	.44 (2)	0.6 (2
Ah. II.	.37 (2)	1.5 (2)
Gw.	.40 (3)	1.6 (3)
Krh.	.41 (1)	0 1 (1)
F.	.375 (11)	....
	29.377	1.00

α Piscium *med.*

$1^h\ 56^m$, $+2^\circ\ 13'$

$\mu = +0^s.0016$ $\mu' = +0''.001$

P.	$21^s.25$ (7)	$57''.4$ (5)
Gr. 72	.22 (3)	56.5 (4)
Gr. 87	.28 (2)	58.7 (2)
F.	.23 (11)	....
	21.236	57.75

γ Ceti.

$2^h\ 37^m$, $+2^\circ\ 46'$

$\mu = -0^s.0114$ $\mu' = -0''.156$

B. J.	$36^s.020$	$18''.25$
Rog.	6.04 (23)	18.6 (19)
Romb.	5.97 (5)	18.5 (3)
Gr. 80.	6.02 (3)	18.4 (14)
F.	6.015 (11)	....
	36.020	18.48

α Ceti.

$2^h\ 56^m$. $+3^\circ\ 39'$

$\mu = -0^s.0029$ $\mu' = -0''.073$

B. J.	$31^s.706$	$27''.88$
F.	.717 (12)	....
	31.717	27.88

f Tauri.

$3^h\ 24^m$, $+12^\circ\ 33'$

$\mu = -0^s.0002$ $\mu' = +0''.011$

B. J.	$47^s.968$	$33''.07$
F.	.963 (12)	....
	47.965	33 07

10 Tauri.

$3^h\ 31^m\ \ +0^\circ\ 3'$

$\mu = -0^s.0159 \quad \mu' = -0''.501$

P.M.C.	15s.53 (4)	6".9 (4)
Gr.60	.54 (9)	6.6 (8)
Gr.64	.60 (3)	7.0 (3)
Cape	.62 (2)	7.7 (2)
Romb.	.59 (4)	6.9 (4)
F.	.48 (10)	....
	15.500	7.82

32 Eridani.

$3^h\ 48^m\ \ -3^\circ\ 16'$

$\mu = +0^s.0019 \quad \mu' = -0''.003$

P.M.C.	46s.08 (4)	50".3 (4)
Cb.	.08 (4)	50.0 (4)
Gr. 80	.11 (3)	49.4 (3)
F.	.01 (10)	.
	46.020	50.00

μ Tauri.

$4^h\ 9^m,\ \ +8^\circ\ 36'$

$\mu = -0^s.0003 \quad \mu' = -0''.012$

P.M.C.	33s.68 (4)	58".9 (4)
Ps.	.68 (13)	58.2 (1)
Gr. 64	.56 (3)	58.8 (3)
Bx.	.63 (2)	61.0 (2)
Rgh.	......	58.6 (20)
F.	.63 (13)	....
	33.635	58.60

ε Tauri.

$4^h\ 22^m,\ \ +18^\circ\ 56'$

$\mu = +0^s.0070 \quad \mu' = -0''.028$

B. J.	11s.591	8".75
F.	.584 (12)	....
	11.588	8.75

π⁵ Orionis.

$4^h\ 48^m,\ \ +2^\circ\ 15'$

$\mu = -0^s.0004 \quad \mu' = -0''.007$

303*	31s.276	36".48
F.	.255 (15)	.....
	31.265	36.48

ο Orionis.

$5^h\ 16^m,\ \ -0^\circ\ 29'$

$\mu = -0^s.0009 \quad \mu' = +0''.009$

P.M.C.	8.85 (4)	29".9 (4)
Cape	.81 (2)	29.5 (2)
Bk.	.81 (4)	29.9 (4)
Gr. 80	.79 (3)	30.0 (4)
F.	.80 (13)	....
	8.801	29.90

119 Tauri.

$5^h\ 25^m,\ \ +18^\circ\ 30'$

$\mu = -0^s.0003 \quad \mu' = -0''.002$

Nb.	45s.83 (32)	42".25 (32)
Gr. 80	.81 (4)	42.1 (4)
Hfk.	.84 (14)	....
F.	.82 (12)	....
	45.831	42.00

γ Geminorum.

$6^h\ 31^m,\ \ +16^\circ\ 29'$

$+0^s.0023 \quad \mu' = -0''.035$

B. J.	21s.441	32".87
F.	.429 (12)	.....
	21.430	32.87

θ Canis Majoris.

$6^h\ 49^m,\ \ -11^\circ\ 54'$

$\mu = -0^s.0105 \quad \mu' = -0''.003$

303*	4s.758	4".45
F.	.723 (12)	....
	4.740	4.45

19 Monocerotis.

$6^h\ 57^m,\ \ -4^\circ\ 4'$

$\mu = -0^s.0014 \quad \mu' = +0''.028$

303*	27s.117	48".63
F.	.080 (12)	.....
	27.099	48.63

23 Hydrae.

$9^h\ 11^m,\ \ -5^\circ\ 53'$

$\mu = +0^s.0015 \quad \mu' = +0''.021$

P.M.C.	13s.99 (4)	40".1 (4)
Cb.	.96 (4)	38.4 (4)
Cape	.89 (2)	41.3 (2)
Gr. 80	.97 (3)	40.8 (6)
Krh.	.99 (5)	39.6 (5)
F.	.97 (10)	...
	13.972	40.56

ι Hydrae.

$9^h\ 34^m,\ \ -0^\circ\ 38'$

$\mu = +0.0049 \quad \mu' = -0''.063$

Pond	14s.32 (10)	37".6 (10)
P.M.C.	.33 (4)	36.3 (4)
Rog.	.30 (19)	38.4 (19)
Gr. 80	.32 (3)	36.9 (3)
Gr. 88	.31 (2)	36.8 (2)
F.	.30 (10)	....
	14.323	37.30

α Leonis.

$10^h\ 2^m,\ +12^\circ\ 30'$

$\mu = -0^s.0182 \quad \mu' = +0''.018$

B. J.	$30^s.807$	$16''.46$
F.	.831 (10)	....
	30.831	16.46

l Leonis.

$10^h\ 43^m,\ +11^\circ\ 7'$

$\mu = -0^s.0015 \quad \mu' = -0''.020$

B. J	$28^s.526$	$37''.35$
Rog.	.520 (32)	37.21 (30)
Romb.	.472 (12)	37.20 (12)
Gr. 80	.499 (29)	38.00 (41)
F.	.498 (13)	.....
	28.499	37.35

p^2 Leonis.

$10^h\ 56^m\ -1^\circ\ 58'$

$\mu = +0^s.0002 \quad \mu' = -0''.010$

303*	$12^s.992$	$32''.57$
F.	.997 (11)	.....
	12.995	32.57

υ Leonis.

$11^h\ 31^m,\ -0^\circ\ 12'$

$\mu = -0^s.0018 \quad \mu' = +0''.047$

B. J.	$18^s.977$	$59''.36$
	.979 (11)	....
	18.978	59.36

95 Leonis.

$11^h\ 50^m,\ +16^\circ\ 15'$

$\mu = -0^s.0004 \quad \mu' = +0''.018$

P.M.C.	$1^s.09$ (4)	$32''.3$ (4)
Gr. 72	.12 (3)	31.8 (4)
Gr. 80	.12 (3)	31.6 (3)
F.	.06 (11)	.....
	1.060	32.20

ϵ Corvi.

$12^h\ 4^m,\ -22^\circ\ 0'$

$\mu = -0^s.0059 \quad \mu' = +0''.021$

303*	$28^s.052$	28.16
F.	.042 (20)	....
	28.047	28.16

c Virginis.

$12^h\ 14^m,\ +3^\circ\ 55'$

$\mu = -0^s.0202 \quad \mu' = -0''.078$

Nb.	45.76 (26)	30.6 (26)
Rgh.	...	30.3 (20)
Gr. 80	.75 (3)	31 8 (2)
Hfk.	.80 (14)	....
F.	.76 (12)	....
	45.756	30.30

δ Virginis.

$12^h\ 50^m\ +3^\circ\ 59'$

$\mu = -0^s.0336 \quad \mu' = -0''.047$

303*	3.707	48.39
F.	.731 (12)	....
	3.719	48.39

B.D.+2°, 2664.

$13^h\ 16^m,\ +2^\circ\ 39'$

$\mu = -0.0070 \quad \mu' = -0''.032$

P.M.C.	6.05 (4)	57.7 (4)
Rog.	.10 (6)	56.8 (6)
Gr. 80	.06 (3)	56.2 (3)
F.	.04 (13)	....
	6.045	56.15

α Virginis.

$13^h\ 19^m,\ -10^\circ\ 35'$

$\mu = -0.0044 \quad \mu' = -0''.018$

303*	$23^s.872$	$12''.80$
Gr. 80	.833 (162)	13.36 (86)
F.	.864 (13)	.....
	23.866	13.36

ϕ Virginis.

$14^h\ 22^m,\ -1^\circ\ 44'$

$\mu = -0^s.0102 \quad \mu' = -0''.002$

B. J.	$32^s.060$	$4''.55$
F.	.049 (11)	.....
	32.055	4.55

μ Virginis.

$14^h\ 37^m,\ -5^\circ\ 10'$

$\mu = +0^s.0056 \quad \mu' = -0''.305$

B. J.	15.761	46.72
F.	.765 (14)	.....
	15.763	46.72

109 Virginis.

$14^h\ 40^m,\ +2^\circ\ 21'$

$\mu = -0^s.0094 \quad \mu' = -0''.027$

B. J.	41 .223	$24''.23$
F	.236 (13)	.....
	41.232	24.23

ε Bootis.

$14^h\ 40^m\quad +27^\circ\ 32'$

$\mu = -0^s.0043 \quad \mu' = +0''.001$

Nb.	10.95 (839)	17.2 (839)
Pulk. '65	.99 (22)	16.9 (22)
Rog.	.97 (13)	17.0 (13)
Romb.	11.01 (13)	17.4 (13)
Gr. 80	10.97 (55)	17.5 (55)
F.	.95 (13)	....
	10.964	16.96

110 Virginis.

$14^h\ 57^m,\quad +2^\circ\ 31'$

$\mu = -0^s.0050 \quad \mu' = +0''.010$

P.M.C.	20.63 (4)	24''.6 (4)
Gr. 60	.58 (3)	24.3 (3)
Gr. 80	.58 (3)	24.9 (3)
F.	.53 (14)	....
	20.580	24.59

3 Serpentis.

$15^h\ 9^m,\quad +5^\circ\ 20'$

$\mu = -0^s.0020 \quad \mu' = +0''.003$

B. J.	43.302	52.94
F.	.235 (11)	.....
	43.257	52.94

β Librae.

$15^h\ 11^m,\quad -8^\circ\ 58'$

$\mu = +0^s.0069 \quad \mu' = -0''.105$

B. J.	5^s.242	35.98
F.	.243 (13)	.....
	5.243	35.98

37 Librae.

$15^h\ 28^m,\quad -9^\circ\ 41'$

$\mu = +0^s.0178 \quad \mu' = -0''.285$

303*	9^s.921	12''.99
Hfk.	.920 (17)	....
F.	.942 (13)	.....
	9.928	12.99

ι Coronae.

$15^h\ 57^m,\quad +30^\circ\ 9'$

$\mu = -0^s.0030 \quad \mu' = -0''.014$

P.M.C.	2^s.28 (4)	32''.3 (4)
Gr. 72	.16 (3)	33.0 (3)
Bk.	.22 (4)	33.5 (4)
F.	.17 (13)	....
	2.170	33.20

δ Ophiuchi.

$16^h\ 8^m,\quad -3^\circ\ 24'$

$\mu = -0^s.0049 \quad \mu' = -0''.137$

B. J.	34.831	38.21
F.	.863 (13)	.....
	34.850	38.21

B. A. C. 5647.

$16^h\ 44^m,\quad +18^\circ\ 27'$

$\mu = -0^s.0028 \quad \mu' = +0''.020$

P. M.	29^s.92 (4)	14''.4 (4)
P.M.C.	30.01 (4)	14.3 (4)
Gr. 80	29.91 (3)	14.6 (3)
F.	29.94 (6)	....
	29.934	14.72

U Ophiuchi.

$17^h\ 10^m,\quad +1^\circ\ 20'$

$\mu = 0^s.000 \quad \mu' = 0''.00$

P.M.C.	56^s.93 (4)	1''.5 (4)
Rog.	.89 (6)	1.7 (6)
Gr. 80	.81 (3)	0.9 (3)
F.	.81 (16)	....
	56.846	1.40

B. A. C. 5903.

$17^h\ 23^m,\quad +0^\circ\ 25'$

$\mu = -0^s.0075 \quad \mu' = 0''.000$

Eh.	12.98 (3)	15.6 (3)
Ah.	12.95 (5)	....
P.M.C.	13.05 (4)	12.2 (4)
Gr.45	13 02 (2)	14.8 (2)
Gr.50	13.03 (3)	....
Bx.	12.86 (4)	12.4 (5)
Gw.	13.01 (2)	10.7 (3)
Gr.80	13.02 (4)	14.3 (4)
F.	12.95 (16)	....
	12.978	14.20

Ll. 32200.

$17^h\ 34^m,\quad -0^\circ\ 34'$

$\mu = 0^s.000 \quad \mu' = 0''.00$

Schj.	18^s.06 (1)	36''.9 (1)
C. B.	.07 (2)	38.3 (2)
Cb.	.08 (3)	40.4 (4)
F.	.07 (16)	....
	18.064	39.00

5 H Scuti.

$18^h\ 37^m,\ -8^\circ\ 22'$

$\mu = -0^s.0004 \quad \mu = +0''.034$

303*	$31^s.794$	$58''.98$
F.	.787 (16)	....
	31.792	58.98

g Aquilae.

$18^h\ 57^m\ -3^\circ\ 51'$

$\mu = +0^s.0013 \quad \mu' = +0''.024$

P.M.C.	$6^s.98$ (4)	$27''.7$ (4)
Rog.	.92 (4)	26.6 (4)
Cb.	.79 (4)	27.6 (4)
F.	.88 (15)	
	6.904	27.14

ν Aquilae.

$19^h\ 20^m,\ +0^\circ\ 7'$

$\mu = -0^s.0025 \quad \mu' = +0''.024$

Ah.	$53^s.58$ (8)	
P.M.C	.50 (4)	11.2 (4)
Bk.	.54 (4)	11.8 (4)
Gr.80	.53 (4)	11.8 (5)
F.	.51 (14	
	53.517	11.55

ι Aquilae.

$19^h\ 31^m,\ -1^\circ\ 31'$

$\mu = -0^s.0024 \quad \mu' = -0''.005$

Pond	1.83 (10)	....
P.M.C.	.85 (4)	47.3 (4)
Gr. 60	.81 (8)	48.1 (4)
Gr. 80	.83 (8)	47.7 (8)
F.	.84 (14)	....
	1.835	47.50

16 Aquarii.

$21^h\ 15^m\ -5^\circ\ 1'$

$\mu = -0.0031 \quad \mu' = +0''.004$

303*	$18^s.266$	$35''.54$

ζ Aquarii *med.*

$22^h\ 23^m\ -0^\circ\ 34'$

$\mu = +0^s.0136 \quad \mu' = +0''.042$

P. '65	10.11 (14)	59.3 (5)
Rog.	.09 (26)	58.0 (25)
Romb.	.10 (8)	58.8 (8)
Gr. 80	.11 (1)	58.4 (1)
F.	.04 (11)	
	10.073	58.07

ζ Pegasi.

$22^h\ 35^m,\ +10^\circ\ 15'$

$\mu = +0^s.0044 \quad \mu' = -0''.018$

B. J.	58.552	25.76
F.	.534 (11)	.....
	58.543	25.76

β Piscium.

$22^h\ 58^m\ +3^\circ\ 18'$

$\mu = -0^s.0003 \quad \mu' = -0''.015$

P.M.C.	$16^s.74$ (4)	$39''.7$ (4)
Cape	.76 (2)	40.2 (3)
Romb.	.77 (2)	40.9 (2)
Gr. 80	.70 (1)	39.9 (1)
F.	.73 (12)	....
	16.730	40.26

φ Aquarii.

$23^h\ 8^m,\ -6^\circ\ 38'$

$\mu = +0^s.0012 \quad \mu' = -0''.188$

Nb.	37.53 (86)	30.9 (86)
P.M.C.	.47 (4)	30.9 (4)
Rog.	.54 (21)	31.2 (21)
Gr. 80	.50 (11)	31.1 (11)
Hfk.	.53 (23)	....
F.	.52 (12)	....
	37.521	30.85

γ Piscium.

$23^h\ 11^m\ +2^\circ\ 40'$

$\mu = +0^s.0487 \quad \mu' = +0''.017$

B. J.	$27^s.742$	52.59
F.	.762 (13)	.....
	27.755	52.59

70 Pegasi.

$23^h\ 23^m\ +12^\circ\ 9'$

$\mu = +0.0018 \quad \mu' = +0''.030$

B. J.	$35^s.459$	$12''.87$
F.	.474 (13)	.....
	35.470	12.87

A^2 Aquarii.

$23^h\ 36^m\ -18^\circ\ 25'$

$\mu = +0^s.0010 \quad \mu' = +0''.022$

P. 65	...	35.60 (24)
Cb.	3.20 (4)	36.5 (4)
Cape	.23 (2)	37.0 (2)
Gr. 80	.15 (3)	35.0 (3)
Gr. 88	.15 (1)	35.9 (1)
F.	.14 (12)	....
	3.140	35.68

In connection with the normal equations resulting from the observations of each pair of stars, pp. 158, 165, there is given the elimination equation for w, the correction to the assumed value of the arc joining each pair of stars. There is also given the value of w obtained by substituting in the elimination equation the values of x, α and β derived from Solution III.

The following table contains a comparison of the resulting distances, $\Delta = D + w$, when corrected for the effect of diurnal aberration, with values of Δ_0 computed from the adopted coordinates of the stars:

COMPARISON OF OBSERVED AND COMPUTED Δ.

Pair	No. Obs.	$D+w$	Di. Ab.	Δ_0	C.–O.	Colors.	$f(\alpha)$	$f(\lambda)$	v
		″	″	″	″		″	″	″
A (1)	16	51.91	+0.02	52.90	+0.97	0 0	−0.50	0.00	+0.03
B (1)	10	20.82	− .03	21.88	+1.09	0 0:	− .40	.00	+ .25
C (1)	10	0.86	− .04	1 45	+0.63	1 2:	− .30	+ .16	+ .05
D (1)	7	18.55	.00	17.77	−0.78	1 3	− 30	+ .21	−1.31
I	12	23.19	+ .03	23.78	+0.56	0 0	− .26	.00	− .14
II	21	4.24	+ .02	5.15	+0.89	1 0	− .16	+ .05	+ .34
III	14	2.44	+ .05	2.98	+0.49	2: 1	.00	+ .16	+ .21
E (1)	7	33.12	− .04	33.97	+0 89	3 4	− .10	+ .37	+ .72
F (1)	23	51.57	.00	52.08	+0 51	1 2	.00	+ .16	+ .23
IV	19	44.41	− .01	45.16	+0.76	0 2	+ .07	+ .11	+ .50
V	21	43.77	+ .01	43.51	−0.27	0 3	+ .19	+ .16	− .36
A (2)	17	40.36	+ .01	40.56	+0.19	0 1	+ .24	+ .05	+ .04
VI	27	44.11	+ .11	43.97	−0 25	3: 3:	+ .30	+ .32	− .07
VII	29	22.21	− .18	21.85	−0.18	2 2:	+ .07	+ .21	− .34
VIII	31	7.56	− .10	7.14	−0.32	4 0:	+ .25	+ .21	− .30
B (2)	20	51.33	+ .02	50.98	−0.37	0: 2	+ .27	+ .11	− .43
IX	26	51.40	− .03	51.45	+0.08	0 1	+ .29	+ .05	+ .02
C (2)	8	11.83	+ .03	12.14	+0.28	2: 0	+ .23	+ .11	+ .18
D (2)	11	15.69	.00	15.57	−0.12	3 1	+ .22	+ .21	− .13
E (2)	12	0.82	− .01	1.73	+0.92	4 0:	+ .16	+ .21	+ .85
F (2)	12	35.75	− .01	35.69	−0.05	2 0	+ .15	+ .11	− .23
A (3)	10	30.52	− .03	30.46	−0.03	1 0:	+ .16	+ .05	− .26

Pair.	*No. Obs.*	*D* + *w*	*Di. Ab.*	Δ_0	*C.—O.*	*Colors.*	*f* (*a*)	*f* (λ)	*v*
		″	″	″	″		″	″	″
X	27	9.76	+0.05	10.22	+0.41	2: 0	+0.17	+0.11	+0.25
XI	1	15.20	.00	15.69	+0.49	1 0	+ .17	+ .05	+ .27
XII	19	58.56	+ .08	58.58	−0.06	2: 2	+ .19	+ .21	− .10
XIII	18	4.78	+ .05	4.42	−0.41	0: 2	+ .19	+ .11	− .55
B (3)	23	4.70	.00	5.17	+0.47	2 0	+ .19	+ .11	+ .33
XIV	43	37.15	− .04	36.73	−0.38	3 3:	+ .19	+ .32	− .31
XV	46	54.15	− .03	53.98	−0.14	3: 1	+ .17	+ .21	− .20
C (3)	15	23.71	+ .01	23.62	−0.10	0 1	+ .13	+ .05	− .36
XVII	30	40.77	+ .02	41.21	+0.42	2 2	+ .10	+ .21	+ .29
D (3)	16	57.08	.00	58.49	+1.41	1 1	+ .10	+ .11	+1.18
XVIII	2	48.06	− .09	48.41	+0.44	1 2:	+ .16	+ .16	+ .32
XIX	18	5.12	− .16	4.91	−0.05	0: 2:	+ .17	+ .11	− .21
XX	32	31.45	+ .04	31.63	+0.14	2: 1	+ .01	+ .16	− .13
E (3)	36	44.69	+ .03	44.67	−0.05	0: 3	.00	+ .16	− .33
XXI	32	37.22	+ .03	37.70	+0.45	2 2	− .08	+ .21	+ .14
F (3)	39	48.07	+ .01	48.14	+0.06	0 1	− .08	+ .05	− .41

The numbers in the column *C.—O.* are the data from which is to be derived the correction to the adopted refractions, but it is to be noted that these numbers depend upon the adopted positions of the fundamental stars contained in the *Berliner Jahrbuch*, and if these positions are affected with any systematic error other than an error of equinox the effects of this error will be perpetuated in the values of *C.—O.* In the table the pairs are arranged in the order of the sidereal times at which the stars composing a pair have equal zenith distances, *i. e.* nearly in the order of right ascension, and the sequence of values of *C.—O.* indicates no marked periodicity such as would be caused by errors in the right ascensions of the clock stars having the form

$$\Delta R.A. = c_1 \sin(\alpha + C_1), \quad \Delta R.A. = c_2, \sin(2\alpha + C_2) \quad \text{etc.}$$

but for the sake of a more careful examination of this matter I have united into means the individual results from pairs having nearly the same right ascension and have placed these in the following table, together with the corresponding results which would have been obtained had the adopted star places used in deriving the computed values of Δ, been referred to the systems of the *Nautical Almanac* and the *Connaissance des Temps* for the epoch 1883. The reductions to these respective systems were de-

rived from the *Tafeln zur Reduction auf das System des Berliner Jahrbuchs*, etc., contained in the appendix to the *Jahrbuch* for 1884. In the computation of these reductions I have assumed that the only systematic error in the star places which can sensibly affect the values of *C.—O.* is the error in the right ascension depending upon the right ascension, *i. e.* that which is usually denoted by the symbol $\Delta\alpha_a$. The first column of the following table contains the limiting values of the sidereal times of observation *T*, of the several pairs united into a mean, the second column the number of such pairs, *n;* and the third, fourth and fifth columns the mean values of *C.—O.* for the three ephemerides. The right ascensions of the *American Ephemeris* differ so little from those of the *Berliner Jahrbuch* that the column *B. J.* may be considered as representing both of these systems. The last column contains the residual *v* obtained by comparing the numbers in the column *B. J.* with the curve of systematic error in the adopted right ascensions, explained below.

VALUES OF C —O.

Limits.	*n*	*B. J.*	*N. A.*	*C. T.*	*v*
h h		″	″	″	″
1.1.... 3.2	2	+1.03	+2.13	+2.42	−0.22
5.5.... 6.4	4	+0.32	+0.80	+0.72	+0.30
7.1.... 7.5	3	+0.70	+0.82	+0.81	−0.28
8.4.... 9.3	4	+0.11	+0.26	−0.20	+0.06
9.9....11.1	4	−0.20	−0.16	−0.56	+0.26
12.9....13.5	2	+0.08	+0.28	−0.22	+0.05
15.0....15.6	2	+0.43	−0.27	−0.33	−0.22
17.5....18.6	4	+0.20	−1.08	−0.74	0.00
18.8....19.6	3	−0.11	−1.11	−0.87	+0.28
20.4... 21.2	3	+0.06	−0.45	−0.31	+0.14
21.6....22.2	4	+0.48	+0.44	+0.49	−0.20
22.7....23.5	3	+0.08	+0.53	+0.61	+0.30

The differences between values of *C—O* which stand in the same line of this table are due solely to the differences between the ephemerides, and the very considerable values which these differences attain, more than a second of arc, illustrate the uncertainty affecting the computed values. The comparisons with the *Nautical Almanac* and the *Connaissance des Temps* show unmistakably a variation depending upon α, having a period of 24^h and a coefficient not much less than one second of arc. The *Berliner Jahrbuch* and *American Ephemeris* seem to be nearly free from error of this

kind, although there is some indication of larger values of $C-O$ at the beginning and end of the column than in the middle, and it is not improbable that this excess denotes a small but real error in the system of right ascensions adopted for the fundamental stars. It does not appear that this variation in the values of $C-O$ can be attributed to the observations since the method of reduction is such that every term having a period of 24^h must have been determined and eliminated through the introduction of the constants α and β.

The differences exhibited by the several columns of the preceding table serve also to emphasize the uncertainty affecting the computed length of any long arc in the heavens. It is probable that the measurement of the distance between two fundamental stars made on a single night with the prism apparatus will furnish a better determination of the length of the arc than can be derived from the tabular right ascensions of the ephemerides.

I have made a graphical adjustment of the quantities contained in the column *B. J.* and from the resulting curve I have determined the corrections $f(\alpha)$ contained in the table at p. 181. By the application of these corrections the observed values of $C-O$ are freed from the effect of the apparent periodic error in the assumed system of right ascensions.

The following additional conclusion with regard to the right ascensions of the stars seems to find its most appropriate place here.

In A Determination of the Solar Parallax from Observations of Mars, Made at the Island of Ascension in 1877, by David Gill, LL.D., the author bases upon a comparison of his heliometer observations of stars with meridian determinations of their places the conclusion that, in general, chronographic determinations of the right ascensions of faint stars make these right ascensions relatively greater than those of brighter stars; *loc. cit.*, p. 78.

It is apparent that if this conclusion is well founded the computed distance separating a pair of stars of different magnitudes will in general be greater than the true distance if the brighter star precedes the fainter star and will be less than the true distance if the preceding star is fainter than the following one. I have therefore, at Dr. Gill's suggestion, examined the observations made with the reel to determine whether any effect of difference of stellar magnitude is shown in the comparison of the measured and computed distances. For this purpose I have employed the thirty-eight residuals, v, of the table at p. 181, arranged in the order of difference of stellar magnitude of the stars composing a pair, this difference being considered positive when the brighter star precedes the fainter.

Giving equal weight to the result from each pair of stars and taking the mean of groups of consecutive values we obtain the following mean results in which a positive sign for v indicates an excess of the computed over the observed value. M denotes

the mean difference of magnitude, m the number of pairs and n the number of observations in each mean value of v.

M	m	n	v
−2.2	8	162	−0.25
−0.8	7	169	−0.09
0.0	8	176	−0.01
+0.4	7	118	+0.09
+1.7	8	180	+0.26

The numbers in this table appear to me to confirm Dr. Gill's conclusion that the right ascensions of the fainter stars are too great, and from a graphical adjustment of the data I find that between the second and seventh magnitudes this excess amounts to $0''.14 = 0^s.009$ per magnitude, for the right ascensions here employed. *Cf.* the Cape Catalogue, 1885, p. xiv. I have made no use of the correction thus determined in the discussion of the observations, since its effect upon the quantities under investigation is evanescent.

A preliminary classification of the values $C—O$ with respect to the type of spectrum assigned to the stars by the Draper Catalogue having rendered probable a dependence of these values upon the character of the light emitted by the star, I have resorted to the following method for a more careful examination of the matter:

Adopting as most convenient for this purpose the development of the refraction in powers of tan z I derive from Resal (*Mécanique Céleste*, p. 431), the following expression for the refraction in zenith distance:

$$\zeta = \alpha\left(1+\frac{3}{2}\alpha-\frac{l}{r_1}\right)\tan z+\alpha\left(\frac{\alpha}{2}-\frac{l}{r_1}\right)\tan^3 z + \quad \ldots\ldots \tag{85}$$

where $\frac{l}{r_1} = 0.0012525553$, is the ratio of the height of the homogeneous atmosphere to the radius of the earth, and

$$\alpha = \frac{n^2-1}{2n^2}$$

n being the index of refraction of air.

According to Kaiser and Runge (*Astronomy and Astro-Physics*, No. 115) we have at 0° C and a barometric pressure of 760^{mm}

$$n = 1.00028817 + 1.316\,\lambda^{-2} + 31600\,\lambda^{-4} \tag{86}$$

which reduced to the normal temperature and pressure of the Pulkowa Refraction Tables becomes

$$n = 1.00027552 + 1.258\,\lambda^{-2} + 30210\,\lambda^{-4} \tag{87}$$

where λ denotes the wave length of the light whose index of refraction is n.

Putting $n — 1 = \mu$, expressing α in terms of μ and passing from the refraction in

zenith distance to the effect of refraction upon the distance Δ between two stars, we obtain

$$R = 2 \tan \frac{\Delta}{2} \left\{ \mu + \frac{\mu^2}{2} \tan^2 z - \frac{l\mu}{r_1} \sec^2 z \right\} \tag{88}$$

Differentiating this expression with respect to μ, we obtain

$$\frac{dR}{d\mu} = \frac{dR}{dn} = 2 \tan \frac{\Delta}{2} \left\{ 1 + \mu \tan^2 z - \frac{l}{r_1} \sec^2 z \right\} \tag{89}$$

and

$$\frac{dR}{d\lambda} = -2 \tan \frac{\Delta}{2} \left\{ 1 + \mu \tan^2 z - \frac{l}{r_1} \sec^2 z \right\} \left(2.516\lambda^{-3} + 120840\lambda^{-5} \right) \tag{90}$$

Introducing numerical values into the expression and putting $\lambda = 589\ \mu\mu$, the D line, we obtain

$$\mu = 0.00027940$$

$$\frac{dR}{d\lambda} = -0''.0100 \left\{ 1 - 0.00067 \sec^2 z \right\} \tag{91}$$

It appears that this differential coefficient is sensibly constant at all zenith distances at which the refraction can be represented by the assumed formula *e. g.* to $z = 79^\circ$. Since the total refraction R is due in equal parts to the refraction suffered by each of the two stars composing a pair, I adopt as the expression for the effect upon R of a deviation $\Delta\lambda$ of the light of one star from an assumed normal wave length

$$\Delta R = -0''.0050\ \Delta\lambda$$

and the total effect upon the refraction will be the sum of the ΔRs contributed by each star of a pair.

In the absence of any means of determining directly the average wave length of the light emitted by the several stars of my observing list, I have had recourse to the color estimates contained in Vogel and Müller's spectroscopic survey (*Publicationen des Astrophysikalischen Observatoriums zu Potsdam, Dritter Band*) supplemented by the Draper Catalogue for the eighteen stars of my list not included within the limits of the former work. The color indications of the Potsdam volume are represented by seven symbols corresponding at the beginning to white and at the end to red light, and the volume furnishes no data for passing from these symbols to the corresponding wave lengths. In the absence of such data I assume that the observers attempted to uniformly divide the color interval from white to red so that the interval between consecutive symbols when measured in terms of sensation, is constant throughout the series. Assuming the psycho-physic law to hold for the color sense the uniformity of the sensation interval furnishes a constant difference in the logarithm of the wave lengths, and if the magnitude and sign of this constant difference in log λ be determined from the values of $C—O$ tabulated above, a very complete check, both upon the legitimacy of the assumptions made and upon the reality of the effect of color upon the observed refractions, may be derived from the condition that the wave

length assigned by the observations to stars designated by the observers as red shall fall in the red part of the spectrum, etc.

The color symbols of the Potsdam volume, the colors which they represent and a number which I have chosen as for my purposes a more convenient symbol are contained in the following table. For those stars whose colors were taken from the Draper Catalogue I have assumed from a comparison of stars common to the two catalogues that the D. C. letters A to D are represented by the number 0; E to K by 2 and M by 3:

TABLE OF SYMBOLS.

No.	Potsdam Symbol.	Color.
0	*W*	White.
1	*G W*	Yellowish white.
2	*W G*	White yellow.
3	*G*	Yellow.
4	*R G*	Ruddy yellow.
5	*G R*	Yellowish red.
6	*R*	Red.

The numbers in the column "Colors" of the table at p. 181, represent the colors of the stars in the manner above determined, those stars whose colors were derived from the Draper Catalogue being indicated by a : after the number. If we denote by l the constant difference between the logarithms of the wave lengths of consecutive color classes it is evident that the number that represents the color of a star represents also the number of ls that must be added to the $\log \lambda$ of a white star in order to obtain $\log \lambda$ for the star in question.

Since we have

$$\varDelta R = -0''.0050\, \varDelta\lambda = -6''.80\, \varDelta \log \lambda$$

it is evident that if we represent by m the sum of the color numbers corresponding to a pair of stars then $-6''.80\, l\, m$ will represent the excess of the actual refraction for such a pair of stars over the refraction for a pair of white stars and putting $6''.80\, l = x$ the correction to the tabular $C—O$ will be $+mx$.. Each $C—O$ furnishes for the determination of x an equation of the form

$$C-O = K-mx$$

where K is the mean value of $C—O$ for white light. The individual equations are so readily formed from the data given in the table that I omit their formal presentation. The normal equations resulting from the thirty-eight pairs of stars are:

$$38K-101x = +11''.35$$
$$-101K+373x = -24''.68$$

The solution of these equations gives

$$K = +0''.439 \pm 0''.096 \qquad x = +0''.053 \pm 0''.031 \qquad l = +0.0078.$$

The constant difference in log λ is therefore 78 units of the fourth decimal place, and if we asssume the D line as corresponding to the wave length of the light of an average yellow star we shall have for the logarithm of the wave length for an average red star

$$\log \lambda = 2.7700 + 0.0078\,(6-3) = 2.7934 \qquad \lambda = 621.5$$

and for an average white star

$$\log \lambda = 2.7700 + 0.0078\,(0-3) = 2.7476 \qquad \lambda = 558.0$$

When the color of a yellow star is identified with the D line the micrometric observations determine the color of an average red star as falling approximately midway between the C and D lines of the spectrum and an average white star as falling between the D and E lines, but nearer to D.

As a control upon the values of x and l above determined, I have submitted to four different persons the *Stern-Spectraltafel* of H. C. Vogel with a request to identify upon it the colors: yellow, ruddy yellow, yellowish red and the superior limit of red. I have also had similar determinations made directly from the prismatic solar spectrum by two persons. The mean wave lengths corresponding to the color symbols as thus determined are:

	G	*R G*	*G R*	*R*	
Spectraltafel	592	606	616	638	$\mu\mu$
Solar Spectrum	589	599	612	631	$\mu\mu$

It is obviously impossible to determine in this manner the wave lengths to associate with any of the symbols involving the letter *W*, white. The two series of results taken separately give as an average value for l, *+110*, *+100*, or excluding the *R*, which from the nature of the case is very poorly determined, $l = 85$ and $l = 80$. Any one of these results differs from the value of l found from the star observations by less than the probable error of the latter and warrants the conclusion that the theoretical effect of the atmospheric dispersion of light is shown in the observations.

After the preceding pages had been written I received from Professor H. C. Vogel, Director of the Potsdam Astro-Physical Observatory, in response to a request for at least an approximate identification of the wave lengths corresponding to the color symbols above employed, the following values of λ, accompanied with the statement that they must be regarded as only rude approximations:

Symbol	*W.*	*GW.*	*WG.*	*G.*	*RG.*	*GR.*	*R.*	
λ	550	560	570	585	595	605	610	$\mu\mu$

The value of l resulting from these numbers is 0.0081, in excellent agreement with that derived from the observations and from the *Spectraltafel*. I adopt the value 0.0078 above derived and have employed Professor Vogel's numbers to determine the

absolute wave length corresponding to the average color of the stars observed, whose mean color number equals 1.1, as follows:

Symbol.	log λ.	Red'n to 1.1	Resulting W. L.	v.
W.	2.7404	+ 86	561 $\mu\mu$	1
G. W.	.7482	+ 8	561	1
W. G.	.7559	− 70	561	1
G.	.7672	−148	565	3
R. G.	.7745	−226	564	2
G. R.	.7818	−304	563	1
R.	.7858	−382	559	3

The resulting wave lengths corresponding to the color number 1.1 are in much better agreement than could be anticipated from the character of the data employed and furnish an excellent control upon the legitimacy of the hypothesis of a constant increment in log λ as well as upon the numerical value of l furnished by the observations. I adopt as the mean wave length of the light of the stars observed

$$\lambda = 562.0 \pm 0.6\ \mu\mu.$$

The results thus obtained may be employed for a determination of the effect of atmospheric dispersion upon the amount of the refraction in zenith distance. Thus from equation 88 we have for the refraction in z

$$R = 206265 \left\{ \mu + \frac{\mu^2}{2} \tan^2 z - \frac{l\mu}{r_1} \sec^2 z \right\} \tan z \tag{92}$$

Differentiating this expression with respect to λ and dividing the result by R, we obtain

$$\frac{\Delta R}{R} = - \frac{\Delta \lambda}{\mu \lambda^3} \left\{ 2.516 + \frac{120840}{\lambda^2} \right\} \left(1 + \frac{\mu}{2} \tan^2 z \right) \tag{93}$$

The last factor in this expression differs so little from unity that as a mean value I put $z = 45°$ and passing to logarithms and introducing the numerical values, $\lambda = 562$ $\mu = 0.0002755$, which correspond to the normal pressure and temperature of the Pulkowa Refraction Tables and the mean wave length of star light, there is obtained in units of the fifth decimal place

$$\Delta \log R = -2.58\, \Delta\lambda \tag{94}$$

where $\Delta\lambda$ is to be expressed in millionths of a millimeter.

This expression shows that at 70° zenith distance the refraction suffered by a yellow star is 0″.3 less than that of a white star, a sufficient indication that for any refined investigation the effect of color upon the refraction is of sensible amount; *e. g.* in determinations of the solar parallax from observations of Mars the tabular refractions employed for the planet are too great and the resulting parallax is too great.

The column $f(\lambda)$ of the table at p. 181, contains the color correction to the refraction, *i. e.* the value of mx, and the column v shows the residual furnished by each pair of stars. There are but two residuals greater than 1″ and as these have opposite signs and occur in triplet D they may arise from the assumed right ascension of the star *B.D.*—0°, 258, being about $0^s.08$ too great. A more plausible explanation may be found in the supposition of systematic errors of bisection in the case of this star which is the faintest in the observing list. Since the micrometer distance, d, is $+4'$ in one of the pairs into which this star enters and $-5'$ in the other pair, such a systematic error would render one of the measured arcs too small and the other too large, but the error would be eliminated from the mean result furnished by the triplet.

By the introduction of the corrections $f(\lambda)$ the $[vv]$ for the C—O is reduced from $7''.45$ to $6''.74$ and the probable error of an average C—O, when due regard is paid to the number of determinations of unknown quantities represented by the graphical adjustment of the periodic errors of the right ascensions, is $\pm 0''.33$, or $\pm 0''.29$ if the effect of error in the right ascension depending upon magnitude be taken into account. This probable error arises from errors of observation and errors in the assumed coordinates of the stars, and assuming the average number of observations of a pair to be 20 we find for the probable error r_1 of an average right ascension:

$$2\,r_1^2 + \frac{(0.30)^2}{20} = (0.33)^2 \qquad r_1 = \pm 0^s.015$$

or

$$2\,r_1^2 + \frac{(0.30)^2}{20} = (0.29)^2 \qquad r_1 = \pm 0^s.013$$

This should be compared with the results of the discussion given by Dr. Auwers (*Astronomische Nachrichten*, No. 2714), where it appears that for the epoch 1891 the corresponding probable error in right ascension of the best determined *Hauptsterne* is $\pm 0^s.014$, *i. e.* the adopted right ascensions upon which the computed distances depend are shown by the observations to have very approximately the same degree of precision as the right ascensions of the best determined fundamental stars. Since the probable error of a computed distance is approximately the same as the probable error of a single observation, I have not assigned weights based upon the number of observations to the several values of C—O, but have given them all equal weight in the determination of a correction to the refraction tables.

This correction must be derived from the excess of the computed, over the measured distance, Δ, and a value of this excess, K, has been already obtained, p. 188. But since this value depends upon the adopted right ascensions of the stars and may be supposed affected by their errors, it should be noted that a value entirely free from the effect of errors of this kind may be obtained from the refraction pairs alone, as

has been already indicated. Taking the mean $C—O$ for the pairs composing each triplet, we obtain the following results:

Triplet.	$C-O$	p
	$''$	
A	+0.38	5
B	+ .49	5
C	+ .40	8

Triplet.	$C-O$	p
	$''$	
D	+0.35	8
E	+ .85	4
F	+ .30	6

The weights given in the column p are computed from the formula

$$\frac{1}{p} = J\left\{\frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}\right\}$$

where J is a constant and the several n's denote the number of observations of each pair of stars composing a triplet. The weighted mean of the several values is

$$K = C-O = +0''.45$$

and the close agreement of this value with that of K above derived from the adopted right ascensions of the stars, $K = +0''.44$, indicates that the effect of the residual systematic error affecting these quantities has been very nearly eliminated.

It is evident that the amount of data is insufficient to furnish a good determination of the probable error of K last derived, but the sum of the weighted squares of the residuals gives $r_0 = \pm 0''.06$, a value materially less than that furnished by all of the pairs of stars when the results are made to depend upon the right ascensions. I adopt as a definitive value

$$K = +0''.44 \pm 0''.05$$

From the value of K a correction to the amount of the tabular refractions is to be derived and if the preceding value be employed for this purpose the result will represent the refraction suffered by white light. For obvious reasons I prefer to adopt as the standard wave length to which the refractions shall be adapted one more nearly corresponding to the average light of the stars, and I assume for this purpose a star whose color is represented by the mean of the color numbers of the sixty-nine stars of my observing list. This mean number is 1.1 corresponding to the wave length 562.0 $\mu\mu$ as above shown, and the corresponding value of K is

$$K = +0''.44 - 1\ 1x = +0''.38.$$

This value of K furnishes a correction to the average refraction for the entire series of observations, and assuming an average temperature of 44° F., a mean barometric pressure of 29.00 English inches and a mean distance between the stars of 120° 2'.5, the average refraction is found to be $R = 195''.0$. If $1+h$ represents the constant factor by which the refractions must be multiplied in order to represent the observations, we have

$$h = +\frac{0.38}{195} \qquad \log(1+h) = \Delta\mu = +0.00085 \pm 11$$

If this quantity be added to the μ of the Pulkowa Tables after the latter have been corrected for gravity and humidity, the resulting refractions will satisfy the observations of stars of average wave length made with the prism apparatus under average atmospheric conditions, between zenith distances 64° and 74°.

One source of difference between the results of the prism work and the refractions of the Pulkowa Tables remains to be considered. Those tables involve as a part of the data from which they were constructed the radius of curvature of the meridian at Pulkowa, and owing to the ellipticity of the earth's figure a small correction is in theory required in order to adapt these tables to another latitude than that for which they were computed.

Since the observations with the prism apparatus were not made in the meridian, it will be necessary to adopt for the radius of curvature of the earth's surface at Madison the radius of the curve cut from this surface by a vertical plane inclined to the meridian at an angle equal to the average azimuth of the stars at the times of observation. Assuming that the average star was in the equator and was observed at an hour angle of 60° this azimuth will be $A = 68^{\circ}.5$, and from the table given at p. 201 of Albrecht's *Formeln und Hülfstafeln* I find in meters the following values of the radius of curvature r_1 of this circle and of the meridians at Madison and Pulkowa:

Place.	Azimuth	log r_1
	°	
Pulkowa	0.	6.80499
Madison	0.	.80377
Madison	68.5	.80511

To determine the effect upon the refraction of variations in r_1 we resume equation (*85*) and find by differentiation

$$d\zeta = \alpha \tan z \sec^2 z \,.\, \frac{l}{r_1} \,.\, \frac{dr_1}{r_1}$$

or

$$\varDelta (\log \zeta) = \varDelta\mu = \sec^2 z \,.\, \frac{l}{r_1} \,.\, \varDelta (\log r_1)$$

where μ is the coefficient given by the Pulkowa Refraction Tables. Introducing the numerical values of $\frac{l}{r_1}$ and $\Delta (\log r_1)$ we obtain in units of the fifth decimal place, the following corrections which should be applied to μ in order to transform its tabular value to that pertaining to the latitude of Madison:

For observations with the reel $\Delta\mu$ in no case amounts to half a unit of the fifth decimal place and may therefore be neglected.

z	$\Delta\mu$	
	$A=0$	$A=68.5$
°		
40	−0.3	+0.0
50	0.4	0.0
60	0.6	0.1
70	1.3	0.1
80	−5.1	+0.5

Collecting the results of the preceding discussions it appears that the correction to the Pulkowa mean refractions may be put in the form:

$$\Delta u = +85 - 7.6\,b + 225 \sin(\varphi' - \varphi) \sin(\varphi' + \varphi) + 2.58\,(562 - \lambda) \tag{95}$$

where all of the coefficients are expressed in units of the fifth decimal place; b, in millimeters, is the mean aqueous vapor tension during clear weather, φ' is the latitude of the place of observation, φ the latitude of Pulkowa, 59°.8, and λ is the equivalent wave length of light of the star whose refraction is to be computed. At Madison $b = 7^{mm}$ and if we assume for Pulkowa $b = 11^{mm}$ the value of $\Delta\mu$, at Pulkowa reduces to 0 for an average star and the tables require no correction.

From a direct comparison of Bessel's refraction tables with those of Pulkowa, I find for zenith distances corresponding to the present series of observation, 64° to 74°, $\alpha - \mu = +114$. We therefore have as the correction to Bessel's mean refractions

$$\Delta \log \alpha = -29 - 7.6\,b + 225 \sin(\varphi' - \varphi) \sin(\varphi' + \varphi) + 2.58\,(562 - \lambda) \tag{95*}$$

Putting $\varphi' = 54°.7$, the latitude of Königsberg, and $b = 10^{mm}$ we find for the factor by which Bessel's mean refractions must be multiplied, 0.9971. To compare with the results obtained by Nobile and Thome, *Saggio di Osservazioni Meridiane Correlative, etc., Napoli, 1893,* I have computed separately the corrections to Bessel's tables for the latitudes of Naples and Cordoba, assuming $b = 8^{mm}$ and $b = 6^{mm}$ respectively and find from the mean of the results that the Bessel mean refractions should be multiplied by the factor 0.9962. The result obtained by Nobile and Thome is 0.9959. The difference of three units in these results is smaller than the probable error of either determination.

In the introduction to the Cape Catalogue for 1885, p. xxxviii, Dr. Gill finds from a comparison of the Greenwich and Cape N. P. D.'s that the Pulkowa tabular refractions must be multiplied by the following factors to represent the observations discussed:

Greenwich,	1 — 0.00054
Cape of Good Hope,	1 — 0.00160.

If we assume for the mean aqueous vapor tension at Greenwich and the Cape respectively 9.5^{mm} and 6.0^{mm}, equation (95) furnishes as the corresponding factors:

Greenwich,	$1 - 0.00044$
Cape of Good Hope,	$1 - 0.00138$

in substantial agreement with the preceding results provided the assumptions with regard to the vapor tension are approximately correct.

With exception of the correction to the refraction tables all of the results derived from the observations with the reel are obtained by a differential process through which the effect of any constant error in the measurement of absolute distances is eliminated. Since the apparatus may be supposed affected with constant errors arising from defects in the figure of the objective, from distortion of the reflecting surfaces or other unknown causes, as a control upon such errors I have derived from the correction to the refraction tables a value of the refractive index of dry air of wave length 589.3 $\mu\mu$, the D line, at a temperature of 0° $C.$ and a barometric pressure of 760^{mm} under standard gravity at latitude 45°. If errors of the kind above suggested are present in the observations their full effect will appear in the refractive index and a comparison of the resulting value with the best laboratory determinations will furnish a test of their presence.

The mean zenith distance at which the observations were made is approximately 69° and corresponding to this zenith distance we have from the Pulkowa Refraction Tables and the preceding investigations

log α	1.75694
sin 1″	4.68557
Reduction to 0° $C.$	+1472
Reduction to 760^{mm}	+ 488
Reduction to 589.3 $\mu\mu$	− 70
Gravity Correction	− 56
Constant	+ 85
$\log \mu \left\{ 1 + \frac{\mu}{2} \tan^2 z - \frac{l}{r_1} \sec^2 z \right\}$	6.46170
μ =	0.00029209 ± 7.10^{-8}

For the sake of comparison with laboratory determinations I annex the corresponding value of n to the following summary of determinations given by Runge, *Astronomy and Astro-Physics*, No. 115:

Epoch	*Observer*	n
1865	Ketteler	1.0002947
1877	Mascart	2927
1880	Lorentz	2911
1888	Benoît	2923
1888	Chappuis and Rivière	2919
1893	Kayser and Runge	2922
1890–91	Comstock	2921

Omitting the discordant result obtained by Ketteler and taking the mean of the following five values, we obtain as the mean result from the laboratory determinations

$$n = 1.00029204$$

differing by only five units in the eighth decimal place from that furnished by the reel. The introduction of a systematic correction of one second of arc to the absolute distances measured with the reel would increase the discordance in the values of n from 5 units to 513 units, and the conclusion seems warranted that the constant error affecting the measurement of absolute distances is very much less than 1″ and probably less than 0″.1.

One further conclusion with regard to the refraction may be drawn from the observations here discussed. It is commonly assumed that the amount of the refraction is subject to "anomalous variations": "From the action of wind and other causes the condition of the air along the path of the ray is seldom perfectly normal; in consequence the actual refraction in any given case is liable to differ from the computed by as much as one or even two per cent." Young, General Astronomy, § 91. "*Neminem fugit, strata aëris inequaliter esse calefacta et hanc ob causam eorum aequilibrium esse perturbatam. Cujus quoniam contrarium debet quaeque theoria supponere, apertum est, theoriam non semper cum observationibus posse consentire, sed mediis tantum refractionum valoribus se applicare.*" Bessel, *Tab. Reg., p. LXII.* Gyldén, Obs. Poulk, Vol. V, p. (23), considers erroneous indications of the external thermometer to be the chief source of such errors in the refraction, and both Bessel and Gyldén *loc. cit.* have determined from their respective observations the probable error of a tabular refraction. For zenith distances included between 65° and 75°, within which the great majority of the observations with the reel were made, these probable errors are represented by the formulae

$$r = 0.0032\,R \quad \textit{Bessel}$$
$$r = 0.0018\,R \quad \textit{Gyldén}$$

where R denotes the amount of the tabular refraction.

The mean value of the tabular refraction for the observations with the reel is $R = 195''$ from which it appears that uncertainty in the refraction should contribute to the probable error of a distance

$$r = \pm 0''.62 \quad \textit{Bessel}$$
$$r = \pm 0''.35 \quad \textit{Gyldén}$$

The observations of the aberration stars show that the total probable error of a single observation is $\pm 0''.296$, and since a considerable part of this value must arise from sources independent of the refraction, it appears that in the present series of observations the refraction is less abnormal than in the work of Bessel and Gyldén. A sufficient cause for this difference may be found in the circumstances under which the observations were made. In the theory of the refraction the atmosphere is as-

sumed to consist of a series of strata of homogeneous air perpendicular to the direction of the vertical. The existence of barometric and thermometric gradients indicates that this condition is oftentimes not fulfilled, and if the strata of homogeneous air are inclined to the plane of the horizon by an angle i, the actual refraction in zenith distance will differ from the tabular refraction by

$$dr = 2 \sin i \operatorname{cosec} 2z \cdot R$$

At a zenith distance of 75° this expression amounts to $0''.24$ for an inclination of $1'$ of arc in the strata and must therefore contribute largely to the probable error of the tabular refraction if that probable error is derived from observations of zenith distance.

The expression for the effect of refraction upon observations with the reel

$$R = 2\,\alpha \tan \frac{\Delta}{2}$$

shows that the effect is nearly independent of the zenith distance (entirely independent save for the small variation of α) and is therefore unaffected by any inclination of the strata.

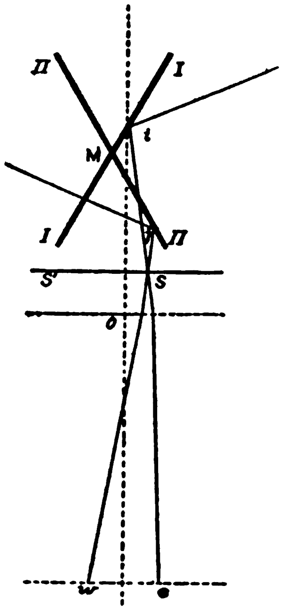
The practical conclusion is that the computed refractions in zenith distance may be made considerably more precise by taking into account the inclination of the strata, *i. e.* the barometric and thermometric gradients. This will be most conveniently done by using as the argument of the tables the zenith distance of the star reckoned from the normal to the strata instead of from the vertical. This of course assumes that the successive strata are concentric, an hypothesis which however much it may be in error, is doubtless much nearer the truth than the one usually made.

EFFECT OF DISTORTION OF THE MIRRORS UPON THE MEASURED DISTANCES OF THE STARS.

In the theory of the apparatus it has been assumed that the faces of the mirrors employed in front of the objective are truly plane surfaces, and since this assumption is certainly not realized in practice it becomes necessary to inquire to what extent a slight deformation of the reflecting surfaces will affect the observations.

Adopting the same sytem of coordinates as that employed for the theory of the apparatus, p. 15, *et seq.*, it is apparent that the only deformation which can sensibly affect the observations is a curvature lying in the plane of xy, and that the effect of such a curvature will be wholly eliminated from the mean of the observations taken in the three positions of the reel if the rays of light incident upon a given mirror in its several positions always fall upon the same part of the mirror, since in this case we may substitute for the distorted surface its tangent plane at the point of incidence. If this condition is not fulfilled a certain amount of error will be introduced into the measured distances and the amount of this error may be investigated as follows:

It is premised that between the reflecting surfaces and the objective an opaque screen was permanently placed and was pierced with three circular apertures each directly beneath one of the mirrors. The primary purpose of this screen was to furnish round star images, but it also serves to determine the point of incidence upon the mirror of the central ray of the pencil producing a given image since this ray must have passed through the center of the corresponding aperture in the screen. In the accompanying figure let *S'S* represent this screen; *S*, the center of an aperture; 0, the optical center of the objective; *I*, the position of a mirror when reflecting rays from an eastern star into the telescope; *II*, the position of the same mirror when reflecting rays from a western star; *e* and *w*, the respective images of these stars formed in the focal plane of the objective. In the case of an actual observation *e* and *w* can never be seen simultaneously, but one of them, *e. g.*, *w*, will be replaced by an image reflected from another mirror occupying very approximately the same position as *II*. Since the angular distance between the images was represented by d in the theory of the apparatus we may assume in the present case for the angular distances of w and e from the optical axis of the telescope kd and $(1-k)d$ where k is a proper fraction whose value will in practice differ but little from one half. The figure shows the course of the rays producing the images of the stars, determined by the condition that they must pass respectively through Sw and Se, and



shows therefore the points of incidence of these rays, i, j, upon the mirrors. Let M denote the intersection of the two positions of the mirror *I* and *II*, and represent the distances Mi, Mj by γ' and γ'' respectively and let α and β be the coordinates of M referred to S as an origin, α being measured parallel to the line of sight; then since each mirror makes an angle of very approximately 30° with the line of sight, we obtain

$$\gamma' \sin 30^\circ = -\beta - \alpha \tan (1-k)\, d$$
$$\gamma'' \sin 30^\circ = -\beta + \alpha \tan k\, d$$

and

$$\gamma'' - \gamma' = 2\, \alpha \tan d$$

an equation which represents the amount by which the points of incidence in the two positions of the mirror differ. If ρ represent the radius of curvature of the mirror we may represent the effect of this alteration in the point of incidence as follows:

$$\Delta = 360^\circ - 2\left(A_1 - A_2 - \frac{2\alpha}{\rho_2}\, d_2\right) + d_3 + K$$
$$= 360 - 2\left(A_2 - A_3 - \frac{2\alpha}{\rho_3}\, d_1\right) + d_1 + K$$
$$= 360 - 2\left(A_3 - A_1 - \frac{2\alpha}{\rho_1}\, d_2\right) + d_2 + K$$

where subscripts to the A and ρ denote the respective mirrors to which the normals and radii of curvature pertain. Taking the mean of these expressions we have, approximately,

$$\Delta = 120^\circ + d + K + 4\alpha \,.\, \frac{1}{8}\left\{\frac{1}{\rho_1} + \frac{1}{\rho_2} + \frac{1}{\rho_3}\right\} d$$

indicating that the effect of curvature of the mirrors is to produce in the resulting Δs an error which may be represented by a constant multiplied by the first power of d. The value of a which appears in the coefficient of d was 132^{mm}. A direct determination of the values of ρ, while the mirrors were mounted in the reel was not readily obtainable, but if we put $\frac{1}{8}\left(\frac{1}{\rho_1} + \frac{1}{\rho_2} + \frac{1}{\rho_3}\right) = \frac{1}{\rho}$ an inferior limit for ρ may be obtained in two ways.

(*a.*) At the beginning of the observations the telescope was carefully focussed after the mirrors had been brought into position and the eye end permanently clamped at the focus of the optical system consisting of objective and mirrors. The value of a revolution of the micrometer screw determined in this position of the threads furnishes as the focal length of the system 2388.5^{mm}, while the focal length of the objective obtained from direct measurements by Bessel's method is 2384.0^{mm}. The difference of 4.5^{mm} in so far as it is not due to error in focussing may be construed as denoting a convex surface for the mirrors having a radius $\rho = 5$ kilometers, but no great confidence can be accorded to this result since the two focal lengths given above depend upon different standard scales which it has been impossible to compare.

(*b.*) For the purpose of obtaining some further idea of the curvature of the mirrors, the mirror occuping the middle position in the reel, Mirror 2, was placed normal to the line of sight of the telescope and the screen between the mirrors and the objective so placed that the line joining the centers of the three apertures in the screen was parallel with the length of the mirror. The telescope having been placed with its line of sight approximately directed to the zenith, two of the apertures in the screen were closed and an image of the micrometer thread, produced by rays of light passing through the central aperture and reflected from the mirror, was brought close beside the real thread as in observations of the nadir with a meridian circle. The ocular having been carefully focussed on the micrometer thread its image appeared fairly well defined. The central aperture in the screen was then closed, the other apertures opened and the images examined to detect any possible shifting in their relative position such as must arise if the reflecting surface were sensibly curved. No such displacement could be detected with a power of 124 diameters, and the image of the micrometer thread appeared as sharp and well defined in the latter case as when produced by rays passing through the central aperture alone.

This sharpness of the image may be used to determine a limiting value of the radius of curvature of the mirror. The thickness of the micrometer threads is approximately $0''.7$ and that of the reflected image (bright threads) somewhat greater, but it may fairly be assumed that if the curvature of the mirror were sufficient to displace

by $0''.5$ the reflected images produced by rays passing through different apertures in the screen the duplicated image of the thread thus produced would present a sensibly altered appearance since its apparent thickness would have been at least doubled. Representing by s the linear distance of the center of an aperture from the optical axis of the objective we have as the expression for the amount of displacement of an image $\frac{2s}{\rho} . 206265$. In the case under consideration s was equal to 51^{mm}, and from the relation

$$\frac{102}{\rho} 206265 < 0.5$$

we obtain $\rho > 42$ kilometers. This value belongs only to the mirror occupying the middle part of the reel, and the construction of the apparatus is such that it is impossible to apply a similar test to the other mirrors. The images of the reflected thread formed by the central portion of Mirrors 1 and 2 were indistinguishable by any difference of appearance to the eye, but the image formed by Mirror 3 was slighly blurred, indicating a different radius of curvature for this mirror. If we assume for this mirror a radius of curvature only half as great as that of 1 and 2, and substitute the resulting values $\rho_1 = \rho_2 = 2\,\rho_3 = 42$ kilometers in the expression for Δ, we shall obtain as the correction due to curvature of mirrors the wholly insignificant quantity $d \div 60000$.

The mirrors were polished and tested while lying upon their backs with the reflecting surface up. The experiment from which the limiting value of the radius of curvature, 42 kilometers, has been derived was conducted with the mirror placed face down and supported at its ends the central parts being free to bend and subjected to a greater bending moment than they could experience in any position occupied by the telescope during the observation of stars. I therefore assume that during the entire series of observations the surfaces of the mirrors were sensibly flat, or differed so little from it that the effect of distortion may be neglected.

SUMMARY OF RESULTS.

The instrument with which the present series of observations was made is an equatorial telescope of six inches (152^{mm}) aperture provided with a system of reflecting surfaces placed in front of its objective, by means of which images of different parts of the heavens may be simultaneously reflected into the telescope. The instrument thus equipped serves to measure the angular distance between stars separated by an arc of approximately 120°. The theory of the apparatus indicates that errors in the adjustment of the reflecting surfaces affect the observed distances only by terms depending upon the squares and higher powers and products of the instrumental errors. These errors were, however, determined from time to time and their effect taken into account in the reduction of the observations.

From the discussion of 822 observations of the angular distances separating 39 pairs of stars, made by two observers, it appears that the apparatus as employed is capable of furnishing a very considerable degree of precision, the probable error of a single observation made under normal conditions being $\pm 0''.30$, *i. e.* less than a millionth part of the quantity measured.

The observations of one of the observers are affected with a personal error whose character and magnitude are determined from a comparison of the measured distances with those computed from the coordinates of the stars. These coordinates were determined from the better modern catalogues supplemented by a series of right ascensions observed for this purpose with the meridian circle of the Washburn Observatory. The average probable error of an adopted right ascension is found from the above comparison to be $\pm 0''.20$, and the declinations, which have only a subordinate influence upon the computed distances, may be assumed to possess nearly the same degree of precision.

The purpose of the observations was to determine from the annual variations in the distance separating each pair of stars a value of the constant of aberration, and from a comparison of the measured with the computed distances to determine corrections to the refraction tables. The latter part of the programme was supplemented by a series of independent measurements of the circumference of the heavens, from which the refraction is to be determined by the condition that the measured circumference plus the refraction must equal 360°.

It was found necessary to conduct a series of subsidiary investigations in connection with the above principal lines of research the results of which may be briefly noted as follows:

A. The indications of a whirled thermometer swung at night, in the open air, are affected with errors which required the substitution of a specially devised ventilating apparatus for the exposure of the thermometers upon whose indications the computed refractions depend.

B. The presence of aqueous vapor in the atmosphere exercises a sensible influence upon the amount of the refraction, and this influence is correctly represented in magnitude and sign by a theoretical formula involving laboratory determinations of the refractive indices and coefficients of expansion of air and aqueous vapor.

C. The atmospheric dispersion produces a sensible effect upon the refractions suffered by stars of different colors. Following the color indications of the Potsdam spectroscopic survey the refraction suffered by a pair of average ruddy-yellow stars is found from observation to be $0''.26$ less than that of a pair of white stars. This result is in substantial agreement with the dispersion formula derived from laboratory experiments by Kayser and Runge.

D. The refractive index, for the D line of the spectrum, of dry air under standard temperature, pressure and gravity is found from the present series of observations to be $1.0002921 \pm 7 \cdot 10^{-8}$. The recent laboratory determinations of this constant accessible to me are included between the limits, 1.0002911 and 1.0002927 and their mean is 1.0002920.

E. The coefficient of expansion of air under constant pressure, per degree centigrade, was determined from observations separated by intervals of only a few days or weeks in order to avoid the effect of any seasonal variation in the refraction not adequately represented by theory. The resulting value, 0.003674, does not sensibly differ from Regnault's laboratory determination.

F. When the coefficient of expansion of air above determined is introduced into the refraction tables, they represent the seasonal variation of the refraction with a high degree of precision. The observations, however, indicate that the tabular refraction requires a small negative correction in the first half of the year and a correspond-g positive correction in the second half.

G. The right ascensions of the *Nautical Almanac* and of the *Connaissance des Temps* for the year 1883, are affected with periodic errors which are functions of the right ascension. These errors, if not altogether absent, appear in much smaller measure in the *American Ephemeris* and the *Berliner Jahrbuch.*

H. Meridian determinations of right ascension in general make the right ascensions of the fainter stars too great. In the places adopted for the present investigation this effect amounts to $0^s.009$ per magnitude.

Of these results C and D depend in part upon the adopted coordinates of the stars, while A, B, E and F, are derived from differences of observed quantities and are therefore free from all assumption with reference to the star places. The close agreement of C and D with the results of laboratory determinations made under entirely different circumstances may be regarded as some indication of the substantial accuracy of the adopted star places, and a further proof is found in the following accordant values of the correction to the average refraction, $R = 195''$, furnished by the Pulkowa Tables for an average pair of stars separated by an arc of approximately 120°:

From the measured circumference of the heavens $\Delta R = +0''.39$
From the assumed coordinates of the stars $\Delta R = +0''.38$.

A correction for the difference in the force of gravity at Pulkowa and Madison is included in this comparison of the tables with observation, and if this term had been omitted the observed correction to the tables would have been less than $0''.1$. This may be regarded as a confirmation of the substantial accuracy of the Pulkowa mean refractions for the latitude of Madison, but in view of the results above designated, B, C and E, it appears that no constant correction to the tables can be made to represent the observations within limits fixed by their own measure of precision. For the adopted form of correction to Bessel's refractions as well as to the Pulkowa Tables, reference may be had to p. 193.

When the results above set forth are duly incorporated with the data directly observed, a solution of the corresponding equations furnishes as a definitive result

$$\text{Constant of Aberration} = 20''.443 \pm 0''.010$$

which differs from the commonly accepted value (Struve) by much less than its own probable error.

It may be noted as a singular coincidence that had all correction for systematic personal error in the observations been omitted, the resulting value of the aberration would have been $20''.499$, a value which is very closely the mean of the more recent determinations of this quantity by other methods.

PUBLICATIONS

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VOL. IX. PART 2.

OBSERVATIONS OF THE RIGHT ASCENSIONS

OF THE

STARS OBSERVED WITH THE PRISM APPARATUS.

1892–'93.

BY ALBERT S. FLINT,
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The Washburn Observatory.

FOUNDED BY

Cadwallader C. Washburn,

Born 1818; Died 1882.

INTRODUCTION.

The purpose of the following observations was the determination of the right ascensions of certain stars observed with the prism apparatus on the six-inch equatorial. The Repsold meridian circle was employed for the work under the same general conditions as during the observations of 1888-'92. A full discussion of the instrument and the method of observing may be found in *Publications of the Washburn Observatory, Vols. II and VIII.* The remarks there given are still applicable except as herein noted. The ocular giving a power of 149 diameters was used throughout The observing was confined to the evening hours and a considerable part of it was done during the very cold winter of 1892-'93. The observer, however, could resort frequently to a warm room in the intervals between transits.

The reductions have been made by Bessel's formula in accordance with the equation,

$$\alpha = T + dr + c' \sec\delta + n \tan\delta + (\Delta T + m),$$

where the terms have their usual significance and are more fully explained in the following. The observed values of the instrumental constants are given in Table I where the columns are explained sufficiently by the headings except the *sixth* and *eighth* columns, which contain the *Hourly Variation of* $\Delta T + m$ and n respectively in units of the third decimal place.

The observed times, T. The chronograph sheets were read to the nearest five-hundredths of a second. Except for circumpolar stars the transits were observed regularly over a standard set of eleven threads in the middle of the reticule. These are arranged in three groups designated by the letters C, D, E, and the threads are denoted individually by the symbols C_1, C_2, C_3, D_1, D_3, D_4, D_5, D_7, E_1, E_2, E_3. Comparatively few observations were made on other than the standard set of threads, but such departure was made regularly in the case of two stars, ϵ Bootis and 109 Virginis at $14^h\ 40^m$ of right ascension, which cross the meridian within 32s. of each other. With a single exception both stars were observed on each date and according to the following program: On the first date the earlier star was observed over the groups C, D, E, the later star over E, F, G; but on the next date the earlier star was observed over A, B, C, and the later star over C, D, E.

From Sept. 28 to Dec. 17, 1892, inclusive, the prism described in *Pub. W. O., Vol. VIII, p. 303*, was used to reverse the apparent motion of the stars, so that the motion over group D was direct in some transits and reversed in others, but always opposite to the motion on C and E. The differences between the means of the times on D and the means of the times on C and E were discussed as follows: Let $T =$ a normal time of transit over the middle thread unaffected by personal error due to the direction of the apparent motion, or by error in the assumed thread intervals; T_i, $T_o =$ the

observed times, reduced to middle thread, when the prism was *in* position and *out* o position respectively; dT = the correction to T_o on account of the direction of the apparent motion when that motion is from *right to left*; k = a coefficient of dT depending upon the declination of the star; $\Delta_1 i$, $\Delta_2 i$ = the means of the assumed thread intervals for group D and for the sum of groups C and E repectively; $di = \Delta_1 i - \Delta_2 i$. Then we have for a star *south* of the zenith observed *Circle West* and with the prism *out* of position on group D

$$T = T_o + k \cdot dT + \Delta_1 i \cdot \sec \delta,$$
$$T = T_i - k \cdot dT + \Delta_2 i \cdot \sec \delta.$$

Subtracting the second equation from the first we have,

$$T_i - T_o = 2k \cdot dT + di \cdot \sec \delta.$$

The sign of the last term in the equation will be changed, evidently, either by the reversal of the instrument or by the transposition of the two positions of the prism. Also, for an upper culmination north of the zenith the sign of the term in dT only is changed, while for a culmination below the pole the sign of the term in di only is changed. The absolute terms of the observation equations were written out according to the following precepts:

STARS SOUTH OF ZENITH OR BELOW THE POLE.

$$+ (T_i - T_o) = 2\,k \cdot dT \pm di \cdot \sec \delta \begin{cases} \text{C. W. } out, \text{ C. E. } in, \\ \text{C. E. } out, \text{ C. W. } in. \end{cases}$$

STARS BETWEEN ZENITH AND POLE.

$$- (T_i - T_o) = 2\,k \cdot dT \pm di \cdot \sec \delta \begin{cases} \text{C. E. } out, \text{ C. W. } in, \\ \text{C. W. } out, \text{ C. E. } in. \end{cases}$$

Where sec δ must be taken negative below the pole, and the terms *out* and *in* denote respectively that the prism was *out* of position or *in* position on the middle group, D. All the observations were included except four which were noted at the time as made under particularly bad conditions.

As a convenient assumption k was put equal to sec δ and the absolute terms $T_i - T_o$ were multiplied by cos δ and thus reduced to the form $2\,dT \pm di$. They were then examined for systematic variation depending upon the declination, but no evidence of such variation was found, and the discussion was made as follows: The quantities $(T_i - T_o)$ cos δ were written in chronological order in two series corresponding respectively to positive and negative signs of di in the formula. The two series were then placed opposite each other and divided into consecutive groups so that the mean epochs of opposite groups were nearly the same. The comparison of the two series is presented in the following table. The means of the groups in the two series are given in the *first* and *third* columns respectively, and the number of observations entering into each mean are given in the *second* column for the first series and in the *fourth* column for the second series. The differences of the numbers in the *first* and

third columns are the values of 2 *di* given in the *fifth* column and the sums are the values of 2 *dT* given in the *sixth* column. The stars observed during the entire interval fall into two distinct groups with reference to the periods of observation, the first extending from 22^h to 1^h, the second from 1^h to 4^h of right ascension. The mean values of 2 *di* and 2 *dT* are given for the two periods and the residual corrections to 2 *dT*, designated by *v*, are given in the last column:

2 *dT* + *di*	n_1	2 *dT* − *di*	n_2	2 *di*	2 *dT*	*v*
SEPTEMBER 28 TO OCTOBER 29, 1892.						
$+0^s.016$	10	$+0^s.017$	10	$-0^s.001$	$+0^s.016$	$-0^s.004$
+ .019	10	+ .029	10	− .010	+ .024	− .012
− .023	10	+ .029	10	− .052	+ .003	+ .010
+ .005	10	+ .009	10	− .004	+ .007	+ .005
+ .019	10	+ .025	10	− .006	+ .022	− .010
− .001	10	+ .019	10	− .020	+ .009	+ .004
+ .016	10	+ .008	10	+ .008	+ .012	.000
+ .022	10	+ .005	10	+ .017	+ .014	− .002
+ .006	10	− .009	10	+ .015	− .002	+ .015
+ .017	15	+ .001	10	+ .016	+ .009	+ .003
− .004	15	+ .045	12	− .049	+ .020	− .008
Means				−0.008	+0.012	
OCTOBER 29 TO DECEMBER 17, 1892.						
−0.026	10	−0.001	8	−0.025	−0.014	+0.007
− .018	10	+ .011	10	− .029	− .004	− .002
+ .004	10	+ .002	10	+ .002	+ .003	− .010
− .001	10	− .015	10	+ .014	− .008	+ .002
− .024	10	− .017	10	− .007	− .020	+ .014
+ .025	10	− .028	10	+ .053	− .002	− .004
− .002	14	.000	13	− .002	− .001	− .006
Means				+0.001	−0.007	

The probable error of a single value of 2 *dT* of the *sixth* column of the table computed from the residuals *v* was found to be $\pm 0^s.0059$. Assuming the probable error

of the transit over a single thread to be $\pm 0^s.030$ for an equatorial star, the theoretical probable error of a single number $2\,dT$ of the table is $\pm 0^s.0040$. Equatorial stars predominate in the observations and three-quarters of the stars, in number, were south of the zenith. The resulting values of dT for the two periods of observation are $+0^s.006 \pm 0^s.001$ and $-0^s.004 \pm 0^s.001$ respectively. These quantities possibly indicate a change in the value of dT, but are so small that they have not been employed as corrections.

Rate, dr. The observed times were corrected for rate of the clock by means of the records of the time service of the observatory, for which the clock correction was observed as a rule once in every two or three days.

Collimation. Under this term was included the instrumental collimation, the diurnal aberration, and the reduction to middle thread. The collimation was observed at least once on each observing date, and this was done at the end of the evening's work or in some interval between transits. The observations of each date were reduced with the value observed on that date, with the exception of two periods indicated in the notes to Table I. The collimation was always determined from observations of the nadir and level, but several methods were employed under different circumstances, as follows: Let D_4, D'_4 denote the middle transit thread and its reflected image respectively, and let M, M' denote the thread of the right ascension micrometer and its reflected image respectively.

When D'_4 was at a convenient distance from D_4 two pointings were made with the right ascension micrometer in the following manner: First, M was so placed that the distance from D_4 to M was bisected by D'_4; and, second, M was run over to the other side of D_4 and so placed that the distance from D'_4 to M was bisected by D_4. The middle thread, D_4, appeared decidedly coarser than the others, and in making the bisections the light-spaces between the threads were made equal instead of the distances between the axes of the threads, so that a correction for the width of D_4, as also of D'_4, was required. The formula employed was

$$c = b \mp \frac{1}{6} \left\{ \left(M_2 - M_1 \right) + d \right\} R \quad \begin{cases} \textit{Image West}, \\ \textit{Image East}. \end{cases}$$

Where c and b denote the collimation and level constants respectively, M_1 and M_2 the two readings of the micrometer, M_2 the larger reading, d the apparent width of D_4, and R the value of one revolution of the right ascension micrometer. The upper sign applies when D'_4 is *west* of D_4, the lower when it is *east*. On some dates D'_4 appeared as a fine line, especially when the eye-piece was focussed on the micrometer thread rather than on the transit threads. In these cases $\frac{1}{2}\,d$ was substituted for d in the preceding expression. The mean value of d from a number of measures made with the right ascension micrometer was $0^r.14$, but the true value is probably a little less.

When the distance of D'_4 from D_4 was very large the coincidence of D_4 with the

right ascension micrometer was observed and also that of D'_4, and the difference of the two readings gave the required distance.

When D'_4 was very close to D_4 or confused with it, the following method, first suggested to me by Mr. A. N. SKINNER of the U. S. Naval Observatory, was adopted. Let a and b denote the parallel threads of the declination micrometer, which are 11″ apart and which were left in a fixed position. Two squares were made by means of the right ascension micrometer. One square was formed by the intersection of M and D_4 with a and b, the other by the intersection of M' and D_4 with a and b. The second square was formed on the opposite side of D_4 from the first square, so that M remained on the same side of D_4 in both positions. It is indifferent on which side of D_4 either square is formed provided the two squares are on opposite sides of D_4. The expression employed is

$$c = b \pm \frac{1}{2}\left(M_2 - M_1\right) R \begin{cases} \textit{Motion Westward,} \\ \textit{Motion Eastward.} \end{cases}$$

Where c, b, M_2, M_1 and R have the same significance as in the formula of the first method. The *upper* sign in the preceding expression applies when the position of the right ascension micrometer in forming the square with M' is *west* of its position in forming the square with M, and the *lower* sign applies when the former position is *east* of the latter position. No correction is required in this method for the width of threads, even if the squares are formed with reference to the light areas between the threads instead of between the axes of the threads. The result by this method is also free from the effect of personal error in estimating the equality of the horizontal and vertical sides of a square, an error which is likely to be considerable. It is not certain, however, that this is a satisfactory method especially when the reflected image of the middle thread is visible more or less plainly, and it was employed in the present work on five dates only and those were not consecutive.

On one occasion the distance between D_4 and D'_4 was deduced from a bisection of the interval between D_4 and the adjacent thread D_3 made with M combined with a bisection of the same interval made with M'; and on one occasion the distance was adopted from a direct estimate.

In May, 1893, suspicion arose as to the trustworthiness of the hanging level. Upon removing it from its mounting the inner surface of the bulb was seen to be pitted. On May 16 one of the collimator level bulbs R 1396 was mounted in the hanging frame and the value of one division investigated by means of the circle microscopes. The adopted value, from eight determinations over large intervals on the scale, is

$$d = 1''.17 \pm 0''.010 \qquad \frac{1}{2} d = 0^s.039 \qquad \textit{Temp.} = 55^\circ \textit{ F.}$$

Bessel's constant n. This was determined from a circumpolar star combined usually with two equatorial stars. A determination was secured near the beginning and end of each night's work, and when the observing extended over more than two or three

hours intermediate determinations were made. The circumpolars regularly observed were α Urs. Min., Gr. 750, 51 H. Cephei, 1 H. Draco., 9 H. Draco., 4 H. Draco., ϵ Urs. Min., δ Urs. Min., λ Urs. Min., 76 Draco. The right ascensions of the *Berliner Jahrbuch* for these stars were corrected by the numbers given in the fourth column of the table in *Pub. W. O. Vol. VIII, p.* 25. Gr. 2373, R. A. $16^h\,35^m$, was observed as a control on the observations of B. A. C. 5647, R. A. $16^h\,42^m$, which was added to the list during the progress of the work. Other circumpolars were employed on several occasions when observations were interrupted by clouds. When the results for the constant n on a given date showed only small variations the mean was adopted; otherwise the adopted values were obtained by linear interpolation between the observed values, and on a number of dates they were read from plotted curves. The inclination of the axis was determined two or more times during each night's observations as a control on the position of the instrument.

Clock corrections and Bessel's constant, m. The values of $\Delta T+m$ depend upon the right ascensions of the *Berliner Jahrbuch* for 1893 and the corrections given in *Pub. W. O. Vol. VIII, pp.* 279-300 for the *622 Sterne.* North of $+10°$ in declination *Hauptsterne* only were employed with the few exceptions noted in the following. South of $+10°$ some *Hauptsterne* contained only in the *622* list were employed, but the *303 Sterne* were preferred and in general adopted. From a comparison of the right ascensions of the 52 stars common to *Vol. VIII* and the *303 Sterne* there was derived a systematic difference in the sense,

$$303\ \textit{Sterne} - \textit{Vol. VIII} = -0^s.025.$$

This was applied in the present work as a correction to the right ascensions of *Vol. VIII* for all stars south of $+10°$. The stars employed fall accordingly into three classes with respect to their assumed right ascensions:

(a). Stars south of $+10°$ in declination and included in the *303 Sterne.* For these the assumed right ascension is the mean of that given in the 303 list and that given by *Vol. VIII* corrected for the systematic difference, $-0^s.025$.

(b). *Hauptsterne* south of $+10°$ and not included in the *303 Sterne.* For these the assumed right ascension is that given by *Vol. VIII* corrected for the systematic difference, $-0^s.025$.

(c). *Hauptsterne* north of $+10°$. For these the assumed right ascension is simply that given by *Vol. VIII.*

The apparent positions were interpolated from the ephemeris of the *Berliner Jahrbuch* in the case of each star observed for which this is given, and for all others observed of the *622 Sterne* the *Bessel's Star-Constants* given in the *Jahrbuch* were employed combined with the *Besselian Star-Numbers* of the *American Ephemeris.* For all the remaining stars observed the apparent right-ascensions were computed by means of the *Independent Star-Numbers* of the *American Ephemeris.*

The clock stars were selected so as to be within the same limits of declination

approximately as the stars whose right ascensions were to be determined. The latter range from $+30°$ to $-22°$, but all except four are between $+19°$ and $-12°$. Wherever a star observed with the prism apparatus was also a standard star it was included in determining $\Delta T+m$, but care was taken to add a sufficient number of independent clock stars properly distributed. The bright stars β Cassiopeiae, α Leonis and α Virginis were not employed as clock stars. The *Zusatzsterne*, δ Arietis, 70 Pegasi and ϕ Pegasi, were included regularly among the clock stars in order to make up for the deficiency of available *Hauptsterne.* The clock stars were distributed throughout the period of observation on each date with few intervals of more than fifteen minutes. In the reductions they were divided into groups of five or more and the adopted values of $\Delta T+m$ were obtained from the means furnished by these groups. In many cases the mean of the several values was adopted for the entire date, and on many dates the adopted values were obtained by linear interpolation between the means of the groups. On a few dates the adopted values were read from curves drawn to represent the means. These last cases are indicated in Table I by dotted lines in the eighth column.

Systematic difference between Circle West and Circle East. The mean result in right ascension Circle *East* was subtracted from the mean result Circle *West* in the case of all stars except circumpolars and others having less than three observations in either position of the instrument. The differences were multiplied by $\cos\delta$ and written in order of declination. The series was then divided into consecutive groups and the means given by the separate groups were plotted. A straight line was drawn as best representing the points, and the adopted expression is

$$W-E = \left\{ 0^{s}.000 + 0^{s}.00067\,\delta \right\} \sec\delta,$$

where δ is the declination expressed in degrees and must be taken with its proper sign. The star farthest south was at $-22°$ declination, and the positions followed one another closely from that limit up to $+31°$, beyond which there were only four stars and they were between $+37°$ and $+58°$ in declination. The means of the groups are given in the first part of the following table in which the headings explain sufficiently the several columns. The tabular corrections to observed right ascensions were computed by the preceding expression and are given in the second part of the table, where the upper sign applies for Circle *West*, the lower for Circle *East*.

SYSTEMATIC DIFFERENCE BETWEEN CIRCLE WEST AND CIRCLE EAST.

Mean *Decl.*	*Number of Stars.*	*Mean* *W−E.*	*Residual* *to Plot.*	*Decl.*	*Tabular Correction.* ± { *Circle West,* *Circle East.*
°		s	s		s
−16.6	12	−0.010	−0.002	−20	±0.007
− 9.8	12	− .004	− .003	−10	± .003
− 5.6	12	− .008	+ .005	0	.000
− 2.6	12	− .009	+ .008	+10	∓ .003
− 0.3	12	− .003	+ .003	+20	∓ .007
+ 2.1	12	+ .010	− .008	+30	∓ .012
+ 3.9	12	+ .008	− .000	+40	∓ .018
+ 7.6	12	− .001	+ .006		
+11.3	12	+ .006	+ .001		
+16.0	12	+ .015	− .005		
+21.2	12	+ .014	− .001		
+35.3	11	+ .026	− .002		

The probable error of a single number contained in the column *W—E* of the preceding table was computed from the numbers in the *fourth* column and found to be $\pm 0^{s}.0033$. The same probable error was computed also from the residuals of the individual stars referred to the means of their respective groups and found to be $\pm 0^{s}.00$ .8. The differences *W—E* from the separate stars were written also in order of right ascension and divided into consecutive groups, but the means given by the separate groups appeared subject only to accidental variations. A similar comparison of results for the same observer in 1891-92, *Pub. W. O., Vol. VIII,* may be presented in connection with the preceding table. These depend, however, upon a much smaller number of observations on each star. The differences were multiplied by cos δ and the mean values are as follows:

Number of Stars.	*Mean of Decls.*	*W−E*
	°	s
10	−14	−0.050
10	+ 6	− .010
10	+20	− .007
13	+48	+ .030

Observed right ascensions. The individual results of the observations are presented in Table II. The assumed mean positions for 1893.0 and the observed corrections to those positions are given for ephemeris stars, and approximate positions and the observed mean right ascensions for 1893.0 are given for all other stars. The assumed mean positions were derived in the manner set forth on p. 212 preceding, and the reductions to mean place were computed as explained on the same page. The mean results for each position of the instrument are presented and in cases where the observations in the two positions are very unequal in number the proper corrections from the table on p. 214 are appended.

Abnormal results are excluded from the means in four cases and these are indicated in the table by brackets. They are probably due to a very poor condition of the star images which was noted at the time. No reductions have been made for proper motion, and the mean places of stars observed in 1892 have been brought to 1893.0 with the Struve precessions.

Catalogue of right ascensions. The concluded right ascensions are given in Table III, together with the mean epoch of observation for each star and the number of observations. The right ascension for each star is the half-sum of the mean results of Table II, *Circle West* and *Circle East*, except in a few cases where the observations in the two positions of the instrument are very unequal in number. In such cases the corrections from the table on p. 214 preceding were applied and the two results combined into a weighted mean with reference only to the number of observations in each position.

The magnitudes are taken from the *Berliner Jahrbuch* or from the observing list for the prism apparatus. Otherwise the several columns are sufficiently explained by their headings.

Probable errors. A comparison has been made of the probable errors of a single observation of right ascension in the present work and the results are presented in the following table in two divisions. The first comparison is between the observing of colder and warmer weather and is based upon all the observations of those stars which were not used in determining the position of the instrument or the clock correction. The second comparison is between brighter and fainter stars. All observations of stars brighter than magnitude 3.0, with the exception of β Cassiopeiae which was regularly used with a circumpolar for determining the position of the instrument, were included in the first group, and all observations of stars fainter than magnitude 5.5 in the second group, in both cases without distinction as to clock stars:

Season of Observation.	Number of Observations.	Number of Stars.	Probable Error.
December, 1892, to April, 1893.	123	11	$\pm 0\overset{s}{.}030$
Sept. to Oct., 1892, April to July, 1893.	261	20	± .020
Class of Stars.			
Mag. 1.2 to 2.7	178	13	±0.021
Mag. 5.5 to 7.2	150	12	± .023

All of the probable errors in the preceding table were computed from residuals derived by comparing the results for the separate dates with the concluded right ascension of each star with no correction to the individual results on account of systematic difference between Circle West and Circle East. The considerable increase of the probable error in the colder season is due perhaps to a combination of unfavorable circumstances among which the greater frequency of a very poor condition of the star images is probably of the most effect. As between brighter and fainter stars there appears to be no material difference in the accidental error of observation. A general value of the probable error of a single right ascension of the present work for equatorial stars was computed from the residuals derived from a comparison of the individual results of Table II with the concluded right ascensions for all stars within 3° of the equator. From the 439 residuals thus derived from 35 stars the resulting value was $\pm 0^s.022$.

A large part of the reductions have been checked by duplicate computations. This includes the means of the transits over the threads, the copying of these means upon the reduction sheets, the application of the sums of the instrumental corrections to the observed times, the interpolation of the ephemeris right ascensions, the comparison of these with the observed right ascensions, the application of the reductions to mean place, the assumed right ascensions, and the derivation of the concluded right ascensions from the individual results. For the rest of the reductions reliance was placed on the agreement of independent results for the detection of errors. Cases that were materially discordant were examined throughout, and whenever an error was found search was made in the remainder of the work for similar errors.

1892.	Sid. Hour.	b	c	$\varDelta T + m$	H. Var. in 0s.001	n	H. Var. in 0s.001
Circle E.	h	s	s	m s		s	
Sept. 23.4	23.0	+0.116	−0.071	−0 2.179	0	+0.456	+ 34
28.4	23.2	+ .356	− .004	+0 0.574	− 75	+ .704	+ 74
29.5	23.1	+ .284	− .016	1.102	+ 26	+ .706	0
Oct. 2.4	23.1	+ .230	− .052	2.852	− 46	+ .744	0
4.4[1]	23.0	+ .393	+ .002	3.668	0	+ .818	0
5.4	23.1	+ .423	+ .014	4.186	0	+ .885	+ 55
8.5	23.1	+ .249	− .005	5.789	0	+ .778	0
Circle W.							
11.4[2]	23.1	+0.200	+0.008	......	.....	......	.....
15.4	23.1	+ .121	+ .008	10.057	0	+0.651	0
18.4	23.1	+ .268	+ .010	11.463	0	+0.914	+ 46
19.4	23.1	+ .386	+ .020	11.975	− 73	+1.053	0
21.4	23.1	+ .242	+ .024	12.889	− 39	+0.962	0
22.4	23.1	+ .256	+ .030	13.868	− 34	+0.955	0
27.4	23.2	+ .153	+ .018	16.576	0	+1.015	0
29.5	2.4	+ .237	+ .025	18.154	− 32	+1.022	+ 32
Nov. 4.5	2.4	+ .086	.000	22.232	+ 37	+1.112	+ 43
Dec. 2.4	3.0	− .158	.000	43.910	0	+0.816	− 21
3.4	2.5	− .153	− .007	44.594	0	+0.924	− 28
4.4	1.3	− .131	− .040	45.115	0	+1.048	0
8.4	2.2	− .044	− .044	46.935	− 34	+1.087	0
10.4	2.2	+ .088	− .027	47.947	− 65	+1.188	0
17.4[3]	2.8	− .060	− .084	52.343	− 69	+1.108	0
1893. *Circle E.*							
Jan. 7.4	2.7	+0.406	+0.089	+1 7.626	0	+1.275	0
10.3[4]	2.4	+ .586	+ .073	10.416	+ 47	+1.493	+ 21
13.3	2.4	+ .608	+ .048	13.038	+ 65	+1.558	+ 26
14.3	2.3	+ .696	+ .052	13.904	0	+1.630	0
16.3	2.4	+ .673	+ .100	16.000	+ 20	+1.500	0

1893.	Sid. Hour.	b	c	ΔT+m	H. Var. in 0s.001	n	H. Var. in 0s.001
Circle E.							
	h	s	s	m s		s	
Jan. 18.4	5.5	+0.526	+0.060	+1 18.153	0	+1.448	+ 26
22.4	5.9	+ .328	− .040	21.370	− 22	+1.472	+ 33
23.5	5.5	+ .437	− .032	22.026	0	+1.541	+ 51
26.4[5]	4.5	+ .689	+ .069	23.459	0	+1.548	+203
29.4[6]	4.5	+ .718	+ .046	25.244	0	+1.568	+193
30.4	5.9	+ .688	+ .026	25.910	− 13	+1.666	+ 57
Feb. 3.4[7]	4.5	+ .864	+ .044	28.927	0	+1.842	+ 79
10.4	6.3	+ .527	+ .022	34.694	+ 25	+1.600	+ 24
Circle W.							
11.5	5.9	+0.687	−0.055	35.508	.....	+1.763	+ 31
12.4	5.9	+ .655	− .032	36.082	0	+1.766	+ 28
15.4	5.3	+ .681	− .072	37.670	.....	+1.848	+ 20
18.3	4.3	+ .699	− .029	39.162	0	+1.807	+ 60
19.3[8]	5.4	+ .608	− .026	39.535	.....	+1.804	+ 70
25.4	6.3	+ .820	+ .008	42.538	0	+1.871	− 46
Mar. 1.4[9]	6.1	− .038	+ .012	44.938	− 42	−0.110	.....
Circle E.							
4.3	6.0	0.000	−0.012	46.433	0	−0.077	− 44
4.5	10.4	− .011	+ .062	46.447	.....	− .211	− 14
17.5	10.4	− .009	+ .041	51.583	− 23	− .095	− 15
19.5	10.4	− .061	+ .081	52.466	− 20	− .238	− 10
25.5	10.4	− .124	+ .076	54.834	− 28	− .310	.....
28.5	10.4	− .218	+ .032	55.875	.....	− .346	0
April 1.4	10.4	− .238	+ .087	57.290	0	− .643	+ 17
2.5[10]	9.9	− .346	− .003	57.667	− 25	− .558	− 51
Circle W.							
3.4[11]	9.0	−0.506	+0.007	57.873	0	−0.754	−302
7.4	9.7	− .414	− .010	......	.....	....	.....
14.4	10.5	− .607	− .039	2 0.438	....	−0.661	0
23.4	10.3	− .737	+ .153	+2 2.651	− 32	−1.127	0

1893.	Sid. Hour.	b	c	$\Delta T+m$	H. Var. in 0s.001	n	H. Var. in 0s.001
Circle W.	h	s	s	m s		s	
April 27.3[12]	9.9	+0.361	+0.092	+2 4.490	0	+0.132	0
May 6.4	14.1	+ .261	− .005	7.579	0	+ .267	0
7.4	13.2	+ .228	− .017	7.973	+ 8	+ .230	0
8.4	12.1	+ .224	− .005	8.287	0	+ .169	0
9.4[13]	11.2	+ .216	− .001	8.627	0	+ .203	0
10.4	12.8	+ .130	− .047	9.028	+ 16	− .048	....
13.4[14]	14.1	+ .480	+ .060	9.890	.....	+ .248	0
14.4[15]	12.2	+ .284	− .068	10.150	0	+ .163	0
16.5[16]	14.7	+ .422	− .019	10.926	0	+ .298	0
17.4	14.1	+ .482	− .077	11.390	0	+ .374	0
Circle E.							
18.4	14.1	+0.444	−0.033	11.597	0	+0.166	0
20.4[17]	12.9	+ .341	− .067	12.220	0	+ .076	0
23.4	14.3	+ .550	− .039	12.852	− 23	+ .333	....
28.4	14.2	+ .500	− .073	14.765	− 14	+ .340	....
29.3	14.2	+ .465	− .052	15.078	− 10	+ .228	0
30.3	14.3	+ .438	− .076	15.417	− 19	+ .239	0
June 15.5	15.4	+ .508	− .030	22.662	0	+ .140	0
16.4	15.4	+ .538	− .061	23.187	0	+ .244	0
16.5	18.2	+ .517	− .077	23.175	− 34	+ .174	+ 34
Circle W.							
19.4	15.5	....	....	24.824	− 47	+0.191	0
19.5	18.2	+0.553	−0.015	24.827	0	+ .149	0
26.5	18.2	+ .655	− .068	27.639	0	+ .421	0
27.5	18.2	+ .718	− .024	28.028	− 20	+ .385	0
28.5	18.3	+ .685	− .014	28.414	0	+ .363	0
July 1.5[18]	17.8	+ .619	− .029	29.568	.....	+ .327	0
3.5	18.3	+ .812	+ .011	30.371	− 37	+ .435	0
8.5	18.3	+ .723	+ .020	+2 32.145	− 32	+ .455	0

1893.	Sid. Hour.	b	c	$\Delta T+m$	H. Var. in 0s.001	n	H. Var. in 0s.001
Circle E.	h	s	s	m s		s	
July 10.5[19]	18.3	+0.735	−0.043	+3 32.924	− 22	+0.446	0
11.5	18.3	+ .633	− .046	33.379	0	+ .340	− 15
15.5[20]	17.8	+ .737	− .002	34.961	0	+ .308	0
17.5	18.3	+ .811	− .033	35.623	0	+ .481	+ 31
18.5[21]	18.2	+ .884	− .097	36.144	0	+ .619	+ 30
19.5	18.2	+ .793	− .077	36.532	0	+ .558	0
21.5	18.2	+ .820	− .082	37.516	0	+ .500	0
22.5[22]	18.2	+ .803	− .099	37.820	.....	+ .459	+ 17
Circle W.							
26.4	16.6	+0.933	−0.028	39.178	0	+0.702	0
28.4	16.6	+ .921	+ .106	39.588	0	+ .504	0
29.4	16.6	+ .831	− .069	40.112	0	+ .735	0

1. A number of stars lost by failure of chronograph.
2. Star observations rejected on account of insufficient illumination.
3. Observations cut off by clouds.
4. Very poor condition of star images, and motion of telescope hard.
5. Observations closed early on account of bad condition of star images.
6. Very bad condition of star images. Observations cut off by clouds.
7. Observations closed early on account of the extremely bad images of southern stars.
8. $\Delta T+m$ applied in three separate mean values to corresponding portions of the observing period.
9. Feb. 27.9. Instrument adjusted in azimuth and level.
10. Observations cut off by clouds.
11. Observations closed early on account of bad conditions of observing. Only three clock stars obtained.
12. April 26.2. Instrument adjusted in azimuth and level.
13. Observations cut off by clouds.
14. $\Delta T+m$. *H. Var.* preceding and following $13^h.8$ adopted as $-0^s.050$ and $+0^s.012$ respectively.
15. Observations cut off by clouds. Only three clock stars obtained.
16. May 16.0. Level bulb *R* 1396, adopted for the hanging level.
17. Observations cut off by failure of chronograph.
18. Observations cut off by clouds.
19. July 10 to July 17 inclusive: adopted the mean of the observed values of *c*, $-0^s.031$.
20. Observations cut off by clouds.
21. July 18 to July 22 inclusive: adopted the mean of the observed values of *c*, $-0^s.089$.
22. Observations interrupted by clouds at $16^h.7$ and $19^h.5$.

β Cassiopeiae.

R. A., 0^h 3^m $28^s.046$.

Dec., 58° 34′.

Circle West.

1892	Oct.	15	+0.10
		18	+ .19
		19	+ .06
		21	+ .04
		22	+ .05
		27	+ .18
Mean			+0.103

Circle East.

1892	Sept.	28	−0.05
		29	.00
	Oct.	2	+ .03
		5	− .03
		8	+ .05
Mean			0.000

ι Ceti.

R. A., 0^h 13^m $58^s.551$.

Dec., −9° 25′.

Circle West.

1892	Oct.	15	−0.05
		18	+ .03
		19	− .06
		21	− .02
		22	− .03
		27	+ .05
Mean			−0.013

Circle East.

1892	Sept.	28	0.00
		29	− .02
	Oct.	2	− .01
		5	+ .05
		8	+ .03
Mean			+0.010

ε Piscium.

R. A., 0^h 57^m $23^s.354$.

Dec., 7° 19′.

Circle West.

1892	Oct.	29	+0.04
	Nov.	4	− .08
	Dec.	3	+ .01
		4	− .09
		8	+ .10
		10	.00
		17	+ .06
Mean			+0.006
Corr.			−0.002
			+0.004

Circle East.

1893	Jan.	10	−0.15
		14	− .06
		16	− .01
Mean			−0.073
Corr.			+0.002
			−0.071

f Piscium.

R. A., 1^h 12^m $16^s.731$[1].

Dec., 8° 8′.

Circle West.

1892	Nov.	4	−0.02
	Dec.	2	+ .08
		3	+ .03
		4	− .03
		8	− .04
		10	+ .14
		17	+ .05
Mean			+0.030

Circle East.

1893	Jan.	7	−0.02
		10	− .11
		13	− .11
		14	+ .02
		16	+ .01
Mean			−0.042

1. Authority, the American Ephemeris for 1893

θ Ceti.

R. A., 1^h 18^m $40^s.498$.

Dec., −8° 44′.

Circle West.

1892	Oct.	29	−0.02
	Nov.	4	− .03
	Dec.	2	− .04
		3	− .06
		4	− .08
		8	− .06
		10	+ .05
		17	+ .01
Mean			−0.029

Circle East.

1893	Jan.	7	+0.04
		10	− .06
		13	− .08
		14	− .04
		16	− .01
Mean			−0.030

μ Piscium.

R. A., 1h 24m.6.

Dec., 5° 34′.

Circle West.

1892	Oct.	29	34.72
	Nov.	4	34.71
	Dec.	3	34.72
		4	34.66
		8	34.64
		10	34.66
		17	34.71
Mean			34.689

Circle East.

1893	Jan.	7	34.72
		10	34.62
		13	34.64
			34.72
		16	34.66
Mean			34.672

η Piscium.

R. A., 1h 25m 45s.392.

Dec., 14° 48′.

Circle West.

1892	Oct.	29	+0.03
	Nov.	4	+ .03
	Dec.	3	.00
		4	+ .04
		8	+ .02
		10	− .01
		17	+0.08
Mean			−0.027

Circle East.

1893	Jan.	7	+0.03
		10	− .06
		13	− .03
		14	− .02
		16	.00
Mean			−0.016

B. D. —0°, 258.

R. A., 1h 34m.6.

Dec., −0° 48′.

Circle West.

1892	Oct.	29	38.54
	Nov.	4	38.56
		3	38.56
		4	[38.68][1]
		8	38.54
		10	38.59
		17	38.54
Mean			38.555

Circle East.

1893	Jan.	7	38.59
		10	38.66
		13	38.52
		14	38.62
		16	38.53
			38.584

1. Only four clock stars and only four threads on this star observed this date. Clouds.

o Piscium.

R. A., 1h 39m 44s.546.

Dec., 8° 37′.

Circle West.

1892	Oct.	29	−0.04
	Nov.	4	+ .03
	Dec.	3	− .01
		4	+ .08
		8	− .02
		10	+ .02
		17	− .03
Mean			+0.004

Circle East.

1893	Jan.	7	−0.01
		10	+ .03
		13	− .03
		14	+ .08
		18	− .02
Mean			+0.010

ζ Ceti.

R. A., 1h 46m 10s.677.

Dec., −10° 52′.

Circle West.

1892	Oct.	29	0.00
	Nov.	4	+ .05
	Dec.	3	+ .04
		8	+ .03
		10	− .09
		17	+ .09
Mean			+0.020

Circle East.

1893	Jan.	7	+0.05
		10	+ .15

1893	Jan.	13	+ .10
		14	+ .09
		16	+ .04
Mean			+0.086

ξ Piscium.

R. A., 1^h 48^m $0^s.940$.

Dec., 2° 40′.

Circle West.

1892	Oct.	29	−0.02
	Nov.	4	+ .01
	Dec.	3	+ .02
		8	− .05
		17	+ .01
Mean			−0.006

Circle East.

1893	Jan.	7	−0.05
		10	+ .11
		13	− .03
		14	− .03
		16	− .02
Mean			−0.004

α Piscium, *med.*

R. A., 1^h $56^m.5$.

Dec., 2 14.

Circle West.

1892	Oct.	29	30.54
	Nov.	4	30.50
	Dec	3	30.52
		8	30.46
		10	30.57
		17	30.57
Mean			30.527

Circle East.

1893	Jan.	7	30.51
		10	30.47
		13	30.61
		14	30.55
		16	30.51
Mean			30.530

67 Ceti.

R. A., 2^h 11^m $38^s.739$.

Dec, −6° 55′.

Circle West.

1892	Oct.	29	0.00
	Nov.	4	− .01
	Dec.	2	− .04
		3	+ .07
		8	+ .01
		10	+ .02
		17	+ .03
Mean			+0.011

Circle East.

1893	Jan	7	+0.03
		10	+ .01
		13[1]	+ .14
		14	− .05
		16	+ .02
Mean			+0.030

1. Seeing very poor on this date until $2^h.8$.

δ Ceti.

R. A., 2^h 33^m $59^s.828$.

Dec., −0° 8′.

Circle West.

1892	Oct	29	−0.01
	Dec.	2	+ .01
		3	− .03
		10	− .07
		17	− .0[illegible]
Mean			−0 024

Circle East.

1893	Jan.	7	−0.02
		10	[+ .28][1]
		13	+ .01
		14	− .03
		16	+ .04
Mean			−0.002

1. Very bad images.

γ Ceti.

R. A., 2^h 37^m $45^s.327$.

Dec., 2° 47′.

Circle West.

1892	Oct.	29	+0.06
	Nov.	4	.00
	Dec.	2	− .01
		3	+ .01
		10	− .06
Mean			0.000

Circle East.

1893	Jan.	7	−0.03
		10	+ .05
		13	− .12
		14	− .01
		16	+ .06
Mean			−0.010

μ Ceti.

R. A., 2^h 39^m $9^s.399$.
Dec., 9° 40′.

Circle West.

1892	Oct. 29	[+0.21][1]
	Nov. 4	+ .09
	Dec. 2	+ .05
	3	+ .03
	10	+ .05
Mean		+0.055

Circle East.

1893	Jan. 7	−0.01
	10	+ .08
	13	+ .01
	14	+ .11
	16	+ .04
Mean		+0.046

1. Very poor image.

41 Arietis.

R. A., 2^h 48^m $41^s.070$.
Dec., 26° 49′.

Circle West.

1892	Oct. 29	+0.04
	Nov. 4	+ .09
	Dec. 2	− .05
	3	− .01
	10	+ .03
	17	+ .11
Mean		+0.035

Circle East.

1893	Jan. 7	−0.01
	10	− .11
	13	+ .06
1893	Jan. 14	− .06
	16	− .04
Mean		−0.032

η Eridani.

R. A., 2^h 51^m $11^s.986$.
Dec., −9° 19′.

Circle West.

1892	Oct. 29	−0.02
	Nov. 4	− .04
	Dec. 2	− .04
	3	− .01
	8	− .06
	10	− .11
	17	+ .03
Mean		−0.036

Circle East.

1893	Jan. 10	+0.02
	13	− .01
	14	− .07
	16	+ .02
Mean		−0.010

α Ceti.

R. A., 2^h 56^m $41^s.105$.
Dec., 8° 40′.

Circle West.

1892	Oct. 29	+0.08
	Nov. 4	+ .13
	Dec. 2	+ .02
	3	+ .03
	8	− .05
	10	− .04
	17	+ .02
Mean		+0.027

Circle East.

1893	Jan. 7	+0.05
	10	− .01
	13	− .04
	14	+ .09
	16	+ .03
Mean		+0.024

δ Arietis.

R. A., 3^h 5^m $30^s.555$.
Dec., 19° 19′.

Circle West.

1892	Oct. 29	+0.01
	Nov. 4	+ .05
	Dec. 2	+ .02
	3	− .01
	8	+ .03
	10	− .01
	17	+ .06
Mean		+0.021

Circle East.

1893	Jan. 7	+0.01
	10	− .02
	13	+ .04
	14	− .05
	16	− .03
Mean		−0.010

ο Tauri.

R. A., 3^h 19^m $3^s.249$.
Dec., 8° 39′.

Circle West.

1892	Oct. 29	+0.02
	Nov. 4	− .07

1892	Dec.	2	+ .00
		3	.00
		8	+ .04
		17	+ .07
Mean			+0.010

Circle East.

1893	Jan.	7	0.00
		10	− .04
		13	+ .09
		14	+ .04
		16	+ .02
Mean			+0.023

f Tauri.

R. A., 3^h 24^m $57^s.872$.

Dec., 12° 34′.

Circle West.

1892	Oct.	29	−0.04
	Nov.	4	− .07
	Dec.	2	+ .03
		3	− .04
		8	+ .03
		10	.00
		17	+ .04
Mean			−0.007

Circle East.

1893	Jan.	7	+0.01
		10	+ .02
		13	.00
		14	+ .01
		16	.00
Mean			+0.008

ε Eridani.

R. A., 3^h 27^m $53^s.335$.

Dec., −9° 49′.

Circle West.

1892	Oct.	29	+0.01
	Nov.	4	.00
	Dec.	2	− .01
		3	− .06
		17	+ .01
Mean			−0.010

Circle East.

1893	Jan.	7	+0.05
		10	− .03
		13	− .04
		14	− .07
		16	.00
Mean			−0.018

10 Tauri.

R. A., 3^h $31^m.4$.

Dec., 0° 4′.

Circle West.

1892	Oct.	29	24.72
	Nov.	4	24.64
	Dec.	2	24.74
		3	24.70
		17	24.67
Mean			24.694

Circle East.

	Jan.	7	24.69
		10	24.61
		13	24 60
		14	24.69
		16	24.69
Mean			24.656

η Tauri.

R. A., 3^h 41^m $7^s.376$.

Dec., 23° 46′.

Circle West.

1892	Oct.	29	+0.05
	Nov.	4	+ .02
	Dec.	2	+ .04
		3	− .04
		10	.00
		17	+ .02
Mean			+0.015

Circle East.

1893	Jan.	7	−0.04
		10	+ .03
		13	+ .03
		14	+ .03
		16	− .06
Mean			−0.004

32 Eridani.

R. A., 3^h $48^m.9$.

Dec., −3° 16′.

Circle West.

1892	Oct.	29	55.03
	Nov.	4	54.98
	Dec.	2	55.05
		3	55.02
		10	55.05
Mean			55.026

Circle East.

1893	Jan.	7	55.06
		10	54.99
		13	55.07
		14	55.08
		16	55.04
Mean			55.048

λ Tauri.

R. A., 8^h 54^m $45^s.063$.

Dec., 12° 11′.

Circle West.

1892	Oct.	29	−0.07
	Nov.	4	− .07
	Dec.	2	+ .01
		3	− .01
		10	+ .04
1893	Feb	11	.00
		12	+ .02
		15	+ .03
		18	+ .07
Mean			+0.002

Circle East.

1893	Jan.	7	−0.03
		10	+ .02
		13	− .01
		14	+ .03
		16	.00
		18	.00
		22	+ .01
		23	+ .04
		29	− .04
		30	.00
Mean			+0.002

ν Tauri.

R A., 3^h 57^m $27^s.818$.

Dec., 5° 42′.

Circle West.

1892	Oct.	29	−0.06
	Nov.	4	− .10
	Dec.	2	+ .03
1892	Dec.	3	+ .01
		10	+ .02
1893	Feb.	11	.00
		12	+ .02
		15	− .03
		18	.00
		19	− .11[1]
Mean			−0.022

Circle East.

1893	Jan.	7	−0.03
		10	− .03
		13	− .02
		14	.00
		16	.00
		18	− .01
		22	+ .03
		23	+ .04
		26	+ .06
		29	.00
		30	+ .01
	Feb.	3	− .02
Mean			+0.002

1. Not included among clock stars.

μ Tauri.

R. A., 4^h $9^m.7$.

Dec., 8° 37′.

Circle West.

1893	Feb.	11	43.44
		12	43.37
		15	43.36
		18	43.40
		19	43.42
Mean			43.398

Circle East.

1893	Jan.	18	43.36
		22	43.38
		23	43.44
		26	43.36
		29	43.34
		30	43.40
	Feb.	3	43.38
Mean			43.380

δ Tauri.

R. A., 4^h 16^m $45^s.804$.

Dec., 17° 17′.

Circle West.

1893	Feb.	15	+0.01
		18	− .06
		19	.00
Mean			−0.017
Corr.			− .006

Circle East.

1893	Jan.	26	−0.05
	Feb.	3	+ .06
Mean			+0.005
Corr.			+ .006

ε Tauri.

R. A., 4^h 22^m $22^s.082$.

Dec., 18° 56′.

Circle West.

1893	Feb.	11	−0.02
		12	− .01
		15	+ .01
		18	− .02
		19	.00
Mean			−0.008

Circle East.

1893	Jan. 18	−0.04
	22	− .01
	23	− .01
	26	+ .04
	29	− .02
	30	.00
	Feb. 3	+ .01
Mean		−0.004

ν Eridani.

R. A., 4^h 30^m $58^s.304$.

Dec., −3° 34′.

Circle West.

1893	Feb. 11	+0.03
	12	+ .05
	15	.00
	18	+ .02
	19	− .01
Mean		+0.018

Circle East.

1893	Jan. 18	+0.03
	22	+ .01
	23	+ .03
	26	+ .08
	29	+ .05
	30	− .02
	Feb. 3	− .01
Mean		+0.024

π^5 Orionis.

R. A., 4^h 48^m $40^s.641$.

Dec., 2° 15′.

Circle West.

1893	Feb. 11	− 0.02
	12	− .02
	15	+ .01
	18	− .01
	19	− .02
	25	− .03
	Mar. 1	+ .01
Mean		+0.007

Circle East.

1893	Jan. 18	−0.03
	22	− .01
	23	− .06
	26	− .06
	29	− .05
	30	− .01
	Feb. 3	− .01
	Mar. 4	.00
Mean		−0.029

β Eridani.

R. A., 5^h 2^m $35^s.351$.

Dec., −5° 13′.

Circle West.

1893	Feb. 11	+0.03
	12	− .05
	15	− .03
	19	− .01
	25	− .12
	Mar 1	− .01
Mean		−0.032

Circle East.

1893	Jan. 18	−0.04
	22	− .02
1893	Jan. 23	− .15
	26	− .05
	29	+ .03
	30	− .04
	Feb. 3	− .08
	10	− .03
	Mar. 4	− .05
Mean		−0.042

o Orionis.

R. A., 5^h $16^m.3$.

Dec., −0° 29′.

Circle West.

1893	Feb. 11	17.90
	12	17.99
	15	18.01
	19	17.98
	25	18.05
	Mar. 1	18.00
Mean		17.988

Circle East.

1893	Jan. 18	17.95
	22	18.00
	23	18.01
	29	17.98
	30	17.98
	Feb. 10	17.95
	Mar. 4	17.98
Mean		17.979

γ Orionis.

R. A., 5^h 19^m $23^s.480$,

Dec., 6° 15′,

Circle West.

1893	Feb. 11	+0.03
	12	+ .04
	15	+ .06
	19	.00
	25	− .01
	Mar. 1	.00
Mean		+0.020

Circle East.

1893	Jan. 18	−0.05
	22	+ .04
	23	+ .06
	29	+ .05
	30	+ .03
	Feb. 10	− .02
	Mar. 4	+ .02
Mean		+0.019

119 Tauri.

R. A., ~~2h~~ 5 $25^m.9$.

Dec., 18° 30′.

Circle West.

1893	Feb. 11	56.32
	12	56.36
	15	56.46
	19	56.31
	25	56.42
	Mar. 1	56.41
Mean		56.380

Circle East.

1893	Jan. 18	56.36
	22	56.36
	23	56.36
	30	56.41
1893	Feb. 10	56.29
	Mar. 4	56.37
Mean		56.358

ι Orionis.

R. A., 5^h 30^m $11^s.912$.

Dec., −5° 58′.

Circle West.

1893	Feb. 11	−0.05
	12	.00
	15	− .03
	19	+ .01
	25	+ .02
	Mar. 1	− .01
Mean		−0.010

Circle East.

1893	Jan. 18	−0.01
	22	− .05
	23	+ .01
	30	− .04
	Feb. 10	+ .01
	Mar. 4	+ .03
Mean		−0.008

κ Orionis.

R. A., 5^h 42^m $40^s.872$.

Dec., −9° 42′.

Circle West.

1893	Feb. 11	−0.05
	12	.00
	15	− .04
	19	+ .01
	25	+ .01
	Mar. 1	− .00
Mean		−0.012

Circle East.

1893	Jan. 18	+0.01
	22	+ .01
	23	− .08
	29	[+ .23][1]
	30	.00
	Feb. 10	+ .03
	Mar. 4	+ .03
Mean		0.000

1. Faint and diffuse. Clouding up.

θ Aurigae.

R. A., 5^h 52^m $25^s.478$.

Dec., 37° 12′.

Circle West.

1893	Feb. 11	+0.06
	12	+ .03
	15	+ .11
	19	+ .01
	Mar. 1	+ .06
Mean		+0.054

Circle East.

1893	Jan. 18	+0.01
	22	+ .02
	23	+ .06
	Mar. 4	+ .09
Mean		+0.045

μ Geminorum.

R. A., 6^h 16^m $29^s.209$.

Dec., 22° 34′.

Circle West.

1893	Feb. 12	+0.06
	15	− .02
	19	− .03

1893	Feb. 25	+ .12
	Mar. 1	+ .03
Mean		+0.032
Corr.		− .008

Circle East.

1893	Jan. 22	+0.04
	30	+ .04
	Feb. 10	+ .02
Mean		+0.033
Corr.		+ .008

10 Monocerotis.

R. A., 6^h 22^m $40^s.541$.

Dec., −4° 41′.

Circle West.

1893	Feb. 11	−0.04
Corr.		+ .002

Circle East.

1893	Jan. 18	+0.01
	Mar. 4	.00
Mean		+0.005
Corr.		− .002

γ Geminorum.

R. A., 6^h 31^m $31^s.822$.

Dec., 16° 29′.

Circle West.

1893	Feb. 11	0.00
	12	.00
	15	− .01
	19	.00
	25	+ .02
	Mar. 1	+ .02
Mean		+0.005

Circle East.

1893	Jan 18	+0.04
	22	+ .02
	23	+ .04
	30	+ .02
	Feb. 10	− .01
	Mar. 4	+ .04
Mean		+0.025

ϵ Geminorum.

R. A., 6^h 37^m $20^s.935$.

Dec., 25° 14′.

Circle West.

1893	Feb. 11	+0.05
	12	+ .00
	15	+ .02
	19	.00
	25	+ .06
	Mar. 1	− .01
Mean		+0.020

Circle East.

1893	Jan. 18	+0.08
	22	+ .05
	23	+ .08
	30	+ .09
	Feb. 10	+ .01
	Mar. 4	− .01
Mean		+0.050

ξ Geminorum.

R. A., 6^h 39^m $17^s.031$.

Dec., 13° 0′.

Circle West.

1893	Feb. 11	+0.04
	12	+ .01
	15	− .04
	19	+ .01
	25	+ .02
	Mar. 1	− .01
Mean		+0.005

Circle East.

1893	Jan. 18	+0.04
	22	− .01
	23	+ .02
	30	− .01
	Feb. 10	+ .01
	Mar. 4	.00
Mean		+0.008

θ Canis Majoris.

R. A., 6^h 49^m $18^s.118$.

Dec., −11° 54′.

Circle West.

1893	Feb. 11	−0.11
	12	− .03
	15	− .06
	19	− .01
	25	− .05
	Mar. 1	+ .04
Mean		−0.037

Circle East.

1893	Jan. 18	−0.01
	22	− .06
	23	− .02
	30	− .09
	Feb. 10	+ .01
	Mar. 4	− .02
Mean		−0.032

19 Monocerotis.

R. A., ~~6^h~~ 57^m $36^s.054$.

Dec., $-4°$ $5'$.

Circle West.

1893	Feb.	11	+0.04
		12	− .05
		15	− .08
		19	− .01
		25	− .06
	Mar.	1	− .06
Mean			−0.037

Circle East.

1893	Jan.	18	−0.06
		22	− .07
		23	− .04
		30	− .03
	Feb.	10	− .04
	Mar.	4	− .05
Mean			−0.048

λ Geminorum.

R. A., 7^h 11^m $56^s.635$.

Dec., $16°$ $43'$.

Circle West.

1893	Feb.	11	+0.03
		12	− .02
		15	+ .06
		19	+ .03
		25	− .03
	Mar.	1	.00
Mean			+0.012

Circle East.

1893	Jan.	18	+0.01
		22	.00
		23	− .01
		30	+ .01
	Feb.	10	− .02
	Mar.	4	− .01
Mean			−0.003

δ Geminorum.

R. A., 7^h 13^m $43^s.958$.

Dec., $22°$ $10'$.

Circle West.

1893	Feb.	11	0.00
		12	.00
		15	+ .12
		19	+ .05
		25	+ .04
	Mar.	1	− .03
Mean			+0.030

Circle East.

1893	Jan.	18	+0.02
		22	+ .02
		23	+ .08
		30	+ .02
	Feb.	10	+ .05
	Mar.	4	+ .01
Mean			+0.033

β Canis Minoris.

R. A., 7^h 21^m $20^s.884$.

Dec., $8°$ $30'$.

Circle West.

1893	Feb.	11	0.00
		12	− .02
		19	− .04
		25	+ .02
Mean			−0.010

Circle East.

1893	Jan.	18	−0.02
		22	− .01
		23	− .10
		30	.00
	Feb.	10	− .02
Mean			−0.030

α Cancri.

R. A., 8^h 52^m $38^s.155$.

Dec., $12°$ $16'$.

Circle West.

1893	Apr.	14	+0.00
		23	− .04
Mean			−0.020
Corr.			−0.004

Circle East.

1893	Mar.	4	−0.02
		17	− .01
		19	− .05
		25	− .04
		28	− .02
	Apr.	1	− .03
		2	− .03
Mean			−0.029
Corr.			+0.004

θ Hydrae.

R. A., 9^h 8^m $47^s.848$.

Dec., $2°$ $45'$.

Circle West.

1893	Apr.	3	+0.03
		14	− .05
		23	− .01
Mean			−0.010
Corr.			− .001

Circle East.

1893	Mar.	4	+0.06
		17	− .03
		19	− .00
		25	− .01
		28	+ .04
	Apr.	1	.00
		2	+ .01
Mean			+0.011
Corr.			+ .001

23 Hydrae.

R. A., 9^h $11^m.4$.

Dec., −5° 54′.

Circle West.

1893	Apr.	3	22.86
		14	22.85
		23	22.97
Mean			22.893
Corr.			+ .002

Circle East.

1893	Mar.	4	22.92
		17	22.88
		19	22.94
		25	22.89
		28	22.97
	Apr.	1	22.91
		2	22.92
Mean			22.919
Corr.			− .002

α Hydrae.

R. A., 9^h 22^m $19^s.742$.

Dec, −8° 11′.

Circle West.

1893	Apr.	14	+0.05
		23	+ .05
Mean			+0.050
Corr.			+ .003

Circle East.

1893	Mar.	17	−0.01
		19	+ .07
		25	.00
		28	+ .14
	Apr.	1	+ .06
		2	+ .05
Mean			+0.052
Corr.			− .003

ι Hydrae.

R. A., 9^h 34^m 4.

Dec, −0° 39′.

Circle West.

1893	Apr.	14	23.50
		23	23.51
		27	23.53
Mean			23.513
Corr.			.000

Circle East.

1893	Mar.	4	23.46
		17	23.48
		19	23.48
		25	23.46
		28	23.54
	Apr.	1	23.49
		2	23.51
Mean			23.481
Corr.			.000

o Leonis.

R. A., 9^h 35^m $26^s.424$.

Dec., 10° 22′.

Circle West.

1893	Apr.	14	0.00
		23	− .04
		27	− .02
Mean			−0.020
Corr.			− .003

Circle East.

1893	Mar.	4	−0.01
		17	− .03
		19	− .06
		25	− .07
		28	.00
	Apr.	1	− .04
		2	− .04
Mean			−0.036
Corr.			+ .003

ε Leonis.

R. A., 9^h 39^m $46^s.681$.

Dec., 24° 16′.

Circle West.

1893	Apr.	14	−0.01
		23	− .01
		27	− .05
Mean			−0.023
Corr.			− .009

Circle East.

1893	Mar.	4	−0.02
		17	+ .01
		19	− .03
		25	− .02

1893	Mar 28	−0.05
	Apr. 1	− .03
	2	− .03
Mean		−0.024
Corr.		+ .009

6 Sextantis.

R. A., 9h 45m 50s.512.

Dec., −3° 44′.

Circle West.

1893	Apr 14	0.00
	23	+ .03
	27	− .01
Mean		+0 007
Corr.		+ .001

Circle East.

1892	Mar. 4	+0.01
	17	+ .02
	19	+ .08
	25	+ .04
	28	+ .09
	Apr. 1	− .01
	2	+ .04
Mean		+0.039
Corr.		− .001

η Leonis.

R. A., 10h 1m 29s.967.

Dec., 17° 17′.

Circle West.

1893	Apr. 14	+0.01
	23	− .04
	27	− .01
Mean		−0.013
Corr.		− .006

Circle East.

1893	Mar. 4	+0.01
	17	− .02
	19	− .08
	25	− .04
	28	− .01
	Apr. 2	− .04
Mean		−0.030
Corr.		+ .006

α Leonis.

R. A., 10h 2m 40s.425.

Dec., 12° 29′.

Circle West.

1893	Apr. 14	+0.02
	23	+ .01
	27	− .03
Mean		0.000
Corr.		− .004

Circle East.

1893	Mar. 4	+0.05
	17	− .02
	19	− .(3
	25	− .01
	28	− .01
	Apr. 1	+ .09
	2	− .01
Mean		+0.009
Corr.		+ .004

λ Hydrae.

R. A., 10h 5m 22s 308.

Dec., −11° 49′.

Circle West.

1893	Apr. 14	−0.03
	23	+ .01
	27	+ .03
Mean		+0.003
Corr.		+ .004

Circle East.

1893	Mar. 17	+0.02
	19	− .04
	25	+ .01
	28	− .02
	Apr. 1	+ .02
	2	− .01
Mean		−0 003
Corr.		− .004

ζ Leonis.

R. A., 10h 10m 44s.371.

Dec., 23° 57′.

Circle West.

1893	Apr. 14	−0.01
	23	− .02
	27	− .03
Mean		−0.020
Corr.		− .009

Circle East.

1893	Mar. 17	0.00
	19	− .06
	25	− .05
	28	− .07
	Apr. 1	− .04
	2	− .03
Mean		−0.042
Corr.		+ .009

μ Hydrae.

R. A., $10^h\ 20^m\ 54^s.920$.
Dec., $-16°\ 17'$.

Circle West.

1893	Apr.	14	−0.03
		23	+ .04
		27	+ .08
	May	7	− .02
		9	− .01
		10	.00
Mean			+0.010

Circle East.

1893	Mar.	4	−0.02
		17	− .01
		19	+ .01
		25	+ .03
		28	.00
	Apr.	1	+ .02
		2	+ .06
Mean			+0.013

33 Sextantis.

R. A., $10^h\ 35^m\ 57^s.558$.
Dec., $-1°\ 10'$.

Circle West.

1893	Apr.	14	+0.05
		23	+ .03
	May	7	+ .01
		8	+ .05
		9	+ .02
		10	+ .01
Mean			+0.028

Circle East.

1893	Mar.	4	+0.04
		17	.00
		19	+ .08
		25	+ .02
		28	+ .03
	Apr.	1	+ .01
		2	+ .04
Mean			+0.031

l Leonis.

R. A., $10^h\ 43^m\ 38^s.017$.
Dec., $11°\ 6'$.

Circle West.

1893	Apr.	14	+0.01
		23	− .06
	May	7	− .07
		8	− .03
		9	− .07
		10	− .05
Mean			−0.045

Circle East.

1893	Mar.	4	−0.01
		17	− .05
		19	− .05
		25	− .04
		28	− .09
	Apr.	1	− .06
		2	− .07
Mean			−0.053

p^2 Leonis.

R. A., $10^h\ 56^m\ 22^s.174$.
Dec., $-1°\ 53'$.

Circle West.

1893	Apr.	23	+0.03
	May	7	− .02
		8	− .01
		10	+ .01
Mean			+0.002
Corr.			+ .001

Circle East.

1893	Mar.	4	−0.03
		17	− .02
		19	+ .03
		25	+ .06
		28	+ .02
	Apr.	1	− .02
		2	− .01
Mean			+0.004
Corr.			− .001

θ Leonis.

R. A., $11^h\ 8^m\ 37^s.525$.
Dec., $16°\ 0'$.

Circle West.

1893	Apr.	23	−0.05
	May	7	− .03
		9	+ .01
		10	− .02
Mean			−0.022
Corr.			− .006

Circle East.

1893	Mar.	4	−0.04
		17	.00
		19	− .03
		25	− .07
		28	− .03

1893	Apr.	1	.00
		2	− .03
Mean			−0.029
Corr.			+ .006

δ Crateris.

R. A., 11^h 13^m $59^s.423$.

Dec., −14° 11′.

Circle West.

1893	Apr.	23	+0.05
	May	7	+ .01
		8	− .01
		9	+ .04
		10	+ .04
Mean			+0.026

Circle East.

1893	Mar.	4	0.00
		17	.00
		19	+ .02
		25	+ .05
		28	+ .01
	Apr.	1	− .02
		2	.00
Mean			+0.009

σ Leonis.

R. A., 11^h 15^m $37^s.126$.

Dec., 6° 36′.

Circle West.

1893	Apr.	23	−0.02
	May	7	− .01
		8	− .04
		9	+ .01
		10	− .02
Mean			−0.016

Circle East.

1893	Mar.	4	+0.04
		17	+ .01
		19	+ .02
		25	− .03
		28	+ .02
	Apr.	1	− .01
Mean			+0.008

υ Leonis.

R. A., 11^h 31^m $28^s.207$.

Dec., −0° 13′.

Circle West.

1893	Apr.	23	−0.05
	May	7	− .02
		8	− .01
		9	− .03
		10	− .04
Mean			−0.030

Circle East.

1893	Mar.	4	−0.02
		17	+ .01
		19	− .02
		25	+ .01
		28	.00
	Apr.	1	− .03
Mean			−0.008

β Virginis.

R. A., 11^h 45^m $7^s.262$.

Dec., 2° 22′.

Circle West.

1893	Apr.	14	+0.01
		23	+ .03
	May	7	+ .02
		8	− .02
		9	+ .02
		10	− .01
Mean			+0.008

Circle East.

1893	Mar.	4	+0.06
		17	+ .04
		19	+ .02
		25	+ .04
		28	+ .03
	Apr.	1	+ .06
Mean			+0.042

95 Leonis.

R. A., 11^h $50^m.3$.

Dec., 16° 14′.

Circle West.

1893	Apr.	14	10.33
		23	10.27
	May	7	10.35
		8	10.34
		9	10.35
		10	10.32
Mean			10.327

Circle East.

1893	Mar.	17	10.35
		19	10.28
		25	10.30
		28	10.34
	Apr.	1	10.30
Mean			10.314

o Virginis.

R. A., 11ʰ 59ᵐ 45ˢ.495.

Dec., 9° 19′.

Circle West.

1893	Apr.	14	+0.04
		23	− .03
	May	7	− .01
		8	+ .04
		10	.00
Mean			+0.008

Circle East.

1893	Mar.	4	+0.01
		17	− .02
		19	− .05
		25	.00
		28	.00
	Apr.	1	+ .01
Mean			−0.008

ε Corvi.

R. A., 12ʰ 4ᵐ 37ˢ.288.

Dec., −22° 1′.

Circle West.

1893	Apr.	14	−0.02
		23	.00
	May	7	+ .02
		8	− .01
		9	+ .02
		10	− .05
		13	+ .03
		14	− .04
		17	− .11
Mean			−0.019

Circle East.

1893	Mar.	4	−0.05
		19	+ .03
		25	− .02
		28	− .01
	Apr.	1	+ .03
	May	18	+ .01
		20	− .03
		23	− .04
		28	− .03
		29	− .01
		30	− .03
Mean			−0.014

γ Corvi.

R. A., 12ʰ 10ᵐ 18ˢ.158.

Dec., −16° 56′.

Circle West.

1893	Apr.	14	+0.04
		23	+ .04
	May	7	+ .01
		8	.00
		9	− .03
		10	.00
		13	+ .02
		14	.00
		17	− .05
Mean			+0.003

Circle East.

1893	Mar.	4	−0.02
		17	+ .02
		19	+ .02
		25	+ .04
		28	− .01
1893	Apr.	1	+ .01
	May	18	.00
		20	− .02
		23	− .03
		28	− .02
		29	+ .04
		30	+ .02
Mean			+0.004

c Virginis.

R. A., 12ʰ 14ᵐ.9.

Dec., 3° 55′.

Circle West.

1893	May	6	54.84
		7	54.90
		8	54.93
		10	54.90
		13	54.96
		14	54.89
		17	54.94
Mean			54.909

Circle East.

1893	May	18	54.89
		20	54.86
		23	54.81
		28	54.93
		29	54.90
Mean			54.878

δ Corvi.

R. A., 12ʰ 24ᵐ 19ˢ.634.

Dec., −15° 55′.

Circle West.

1893	May	6	−0.03
		7	+ .01
		8	− .01
		10	− .03
		13	+ .03
		14	+ .02
		17	− .03
Mean			−0.006

Circle East.

1893	May	18	+0.03
		20	+ .05
		23	.00
		28	+ .01
		29	.00
		30	+ .01
Mean			+0.017

δ Virginis.

R. A., 12^h 50^m $12^s.756$.

Dec., 3° 58′.

Circle West.

1893	May	6	−0.08
		7	+ .04
		8	+ .05
		10	+ .03
		13	+ .05
		17	+ .07
Mean			+0.027

Circle East.

1893	May	18	+0.07
		20	+ .05
		23	+ .05
		28	+ .04
		29	− .01
		30	.00
Mean			+0.033

ε Virginis.

R. A., 12^h 56^m $51^s.021$.

Dec., 11° 32′.

Circle West.

1893	May	6	−0.01
		7	− .03
		8	.00
		10	− .02
		13	− .01
		16	− .04
		17	+ .(6
Mean			−0.007

Circle East.

1893	May	18	−0.04
		20	− .03
		23	− .04
		28	− .02
		29	− .01
		30	− .02
Mean			−0.027

θ Virginis.

R. A., 13^h 4^m $24^s 544$.

Dec., −4° 58′.

Circle West.

1893	May	7	+0.05
		8	+ .05
		10	+ .01
		13	− .05
		16	.00
		17	− .04
Mean			+0 003

Circle East.

1893	May	18	−0.01
		20	− .04
		23	− .02
		28	+ .03
		29	− .02
		30	.00
Mean			−0.010

B. D.+2°,2664.

R. A., 13^h $16^m.3$.

Dec., 2° 38′.

Circle West.

1893	May	6	15.17
		7	15.18
		8	15.19
		10	15.19
		13	15.16
		16	15.13
		17	15.17
Mean			15.170

Circle East.

1893	May	18	15.18
		20	15.17
		23	15.18
		28	15.16
		29	15.19
		30	15.17
Mean			15.175

α Virginis.

R. A., 13h 19m 33s.345.
Dec., −10° 36′.

Circle West.

1893	May	6	−0.06
		7	+ .02
		8	− .04
		10	− .03
		13	− .02
		16	− .04
		17	− .04
Mean			−0.030

Circle East.

1893	May	18	−0.02
		20	.00
		23	− .03
		28	− .04
		29	− .04
		30	+ .02
Mean			−0.017

ζ Virginis.

R. A., 13h 29m 14s.402.
Dec., −0° 2′.

Circle West.

1893	May	7	+0.01
		8	− .04
		10	+ .02
		13	+ .04
		16	− .01
		17	+ .01
Mean			+0.005

Circle East.

1893	May	18	0.00
		20	+ .03
		23	+ .03
		28	+ .04
		29	+ .04
		30	+ .03
Mean			+0.028

τ Bootis.

R. A., 13h 42m 10s.637.
Dec., 17° 59′.

Circle West.

1893	May	6	−0.02
		7	.00
		13	+ .01
		16	− .03
		17	+ .06
Mean			+0.004

Circle East.

1893	May	18	−0.01
		20	− .03
		23	.00
		28	− .03
		29	− .01
		30	− .01
Mean			−0.015

89 Virginis.

R. A., 13h 44m 3s.420.
Dec., −17° 36′.

Circle West.

1893	May	6	−0.04
		7	+ .03
		13	− .03
		16	− .01
		17	− .02
Mean			−0.014

Circle East.

1893	May	18	+0.05
		20	+ .01
		23	− .03
		28	+ .02
		29	− .05
		30	+ .04
Mean			+0.007

η Bootis.

R. A., 13h 49m 35s.382.
Dec., 18° 56′.

Circle West.

1893	May	6	0.00
		7	− .05
		13	+ .03
		16	− .02
		17	+ .06
Mean			+0.004

Circle East.

1893	May	18	−0.02
		23	− .02
		28	− .01
		29	+ .01
		30	− .02
Mean			−0.012

τ Virginis.

R. A., 13^h 56^m $12^s.012$.

Dec., $2°$ $3'$.

Circle West.

1893	May	6	− 0.03
		7	.00
		10	+ .05
		13	+ .03
		16	− .04
		17	+ .02
Mean			+0.005

Circle East.

1893	May	18	−0.02
		23	− .02
		28	.00
		29	+ .01
		30	.00
Mean			−0.006

ι Virginis.

R. A., 14^h 10^m $24^s.161$.

Dec., $-5°$ $29'$.

Circle West.

1893	May	6	−0.01
		7	+ .01
		10	.00
		13	− .01
		16	+ .01
		17	+ .05
Mean			+0 008

Circle East.

1893	May	18	−0.01
		23	.00
		28	.00
1893	May	29	− .02
		30	− .02
Mean			−0.010

ϕ Virginis.

R. A., 14^h 22^m $41^s.313$.

Dec., $-1°$ $44'$.

Circle West.

1893	May	6	+0.02
		7	+ .01
		10	− .02
		13	− .04
		16	+ .01
		17	− .06
Mean			−0.013

Circle East.

1893	May	18	0.00
		23	− .01
		28	+ .04
		29	− .02
		30	− .01
Mean			0.000

ρ Bootis.

R. A., 14^h 27^m $13^s.112$.

Dec., $30°$ $50'$.

Circle West.

1893	May	6	+0.05
		7	− .04
		10	− .06
		16	.00
		17	+ .03
Mean			−0.004

Circle East.

1893	May	18	−0.04
		23	− .02
		28	− .06
		29	− .04
		30	+ .01
Mean			−0.030

π Bootis *pr.*

R. A., 14^h 35^m $41^s.816$.

Dec., $16°$ $52'$.

Circle West.

1893	May	6	+0.07
		7	+ .02
		10	− .01
		13	+ .01
		16	+ .06
		17	+ .08
Mean			+0.038

Circle East.

1893	May	18	+0.01
		23	+ .05
		28	− .01
		29	.00
	June	15	− .05
		16	.00
Mean			0.000

μ Virginis.

R. A., 14^h 37^m $25^s.226$.

Dec., $-5°$ $11'$.

Circle West.

1893	May	6	−0.01
		7	+ .01

1893	May	10	− .01
		13	.00
		16	− .01
		17	+ .01
	June	19	+ .02
Mean			+0.001

Circle East.

1893	May	18	−0.01
		23	+ .02
		28	+ .01
		29	.00
		30	.00
	June	15	− .03
		16	+ .03
Mean			+0.003

ε Bootis (a).

R. A., 14^h 40^m $18^s.907$[1].

Dec., 27° 31′.

Circle West.

1893	May	6	−0.07
		7	− .14
		13	− .10
		16	− .07
		17	− .07
	June	19	− .09
Mean			−0.090

Circle East.

1893	May	18	−0.09
		23	− .07
		28	− .11
		29	− .09
		30	− .08

1. Authority, American Ephemeris, 1893.

1893	June	15	− .14
		16	− .13
Mean			−0.101

109 Virginis.

R. A., 14^h 40^m $50^s.306$.

Dec., 2° 20′.

Circle West.

1893	May	6	+0.06
		7	− .04
		10	− .01
		13	+ .03
		16	.00
		17	+ .02
Mean			+0.010

Circle East.

1893	May	18	0.00
		23	+ .02
		28	+ .02
		29	− .01
		30	.00
	June	15	+ .02
		16	+ .04
Mean			+0.013

110 Virginis.

R. A., 14^h $57^m.5$.

Dec., 2° 30′.

Circle West.

1893	May	6	29.64
		7	29.64
		10	29.63
		13	29.61
		16	29.61
		17	29.59
	June	19	29.63
Mean			29.621

Circle East.

1893	May	18	29.58
		23	29.59
		28	29.60
		29	29.61
		30	29.55
	June	15	29.58
		16	29.62
Mean			29.590

ι Librae.

R. A., 15^h 6^m $7^s.268$.

Dec., −19° 23′.

Circle West.

1893	May	6	+0.02
		7	+ .03
		13	+ .01
		16	− .03
		17	− .07
	June	19	− .03
Mean			−0.012

Circle East.

1893	May	18	−0.01
		23	− .07
		28	.00
		29	+ .04
		30	− .01
	June	15	+ .02
		16	− .02
Mean			−0.007

3 Serpentis.

R. A., 15^h $9^m.9$.

Dec., 5° 20′.

Circle West.

1893	May	6	52.20
		7	52.17
		13	52.18
		16	52.18
		17	52.15
	June	19	52.18
Mean			52.177

Circle East.

1893	May	23	52.16
		28	52.13
		29	52.17
	June	15	52.18
		16	52.17
Mean			52.162

β Librae.

R. A., 15^h 11^m $14^s.896$.

Dec., −8° 59′.

Circle West.

1893	May	6	+0.01
		7	.00
		10	+ .08
		13	− .02
		16	+ .02
		17	− .01
	June	19	.00
Mean			+0.011

Circle East.

1893	May	23	+0.02
		28	+ .06
1893	May	29	.00
		30	.00
	June	15	.00
		16	−0.05
Mean			+0.005

β Coronae Borealis.

R. A., 15^h 23^m $25^s.050$.

Dec., 29° 28′.

Circle West.

1893	May	6	−0.03
		7	− .03
		13	− .03
		16	− .02
		17	− .02
	June	19	− .02
Mean			−0.025

Circle East.

1893	May	18	−0.12
		23	− .02
		28	− .05
		29	− .05
		30	− .07
	June	15	− .04
		16	− .04
Mean			−0.056

37 Librae.

R. A., 15^h 28^m $19^s.732$.

Dec., −9° 41′.

Circle West.

1893	May	6	+0.05
		7	+ .09
		13	.00
1893	May	16	+ .01
		17	+ .01
	June	19	− .01
Mean			+0.025

Circle East.

1893	May	18	+0.01
		23	+ .01
		28	.00
		29	+ .03
		30	+ .02
	June	15	+ .02
		16	+ .01
Mean			+0.014

β Serpentis.

R. A., 15^h 41^m $14^s.955$.

Dec., 15° 45′.

Circle West.

1893	May	6	−0.03
		7	− .05
		13	− .02
		16	− .01
		17	− .01
	June	19	+ .01
Mean			−0.018

Circle East.

1893	May	18	−0.06
		23	− .03
		28	− .03
		29	− .03
		30	− .06
	June	15	− .03
		16	− .01
Mean			−0.036

ε Coronae Borealis.

R. A., $15^h\ 58^m\ 9^s.424$.

Dec., 27° 11′.

Circle West.

1893 May	6	+0.02
	7	+ .03
	13	+ .01
	16	− .01
	17	+ .05
June	19	+ .01
Mean		+0.018

Circle East.

1893 May	18	0.00
	23	+ .04
	28	+ .04
	29	.00
	30	+ .03
June	15	− .01
	16	+ .02
Mean		+0.017

ι Coronae Borealis.

R. A., $15^h\ 57^m.2$.

Dec., 30° 8′.

Circle West.

1893 May	6	9.41
	7	9.38
	13	9.43
	16	9.37
	17	9.40
June	19	9.34
Mean		9.388

Circle East.

1893 May	18	9.35
	23	9.35
	28	9.42
	29	9.34
	30	9.36
June	15	9.31
	16	9.35
Mean		9.354

δ Ophiuchi.

R. A., $16^h\ 8^m\ 44^s.236$.

Dec., −3° 25′.

Circle West.

1893 May	6	+0.05
	7	+ .01
	13	+ .04
	16	+ .03
	17	+ .02
June	19	+ .04
Mean		+0.032

Circle East.

1893 May	18	+0.05
	23	+ .03
	28	+ .02
	29	+ .06
	30	+ .04
June	15	+ .07
	16	+ .06
Mean		+0.047

ε Ophiuchi.

R. A., $16^h\ 12^m\ 39^s.542$.

Dec., −4° 25′.

Circle West.

1893 May	16	+0.01
	17	.00
June	19	− .01
Mean		0.000
Corr.		+ .015

Circle East.

1893 May	18	+0.03
	28	− .01
	29	+ .05
	30	+ .01
June	15	+ .03
	16	− .01
Mean		+0.025
Corr.		− .015

γ Herculis.

R. A., $16^h\ 17^m\ 11^s.993$.

Dec., 19° 24′.

Circle West.

1893 May	16	+0.02
	17	− .03
June	19	− .06
Mean		$-0.02\cancel{7}$ 3
Corr.		− .007

Circle East.

1893 May	18	−0.05
	23	− .04
	28	− .05
	29	− .03
	30	− .06
June	15	− .03
	16	− .04
Mean		−0.043
Corr.		+ .007

β Herculis.

R. A., 16^h 25^m $37^s.186$.

Dec., 21° 48′.

Circle West.

1893	July 26	−0.05
Corr.		− .008

Circle East.

1893	July 19	−0.05
	21	− .04
	23	.00
Mean		−0.030
Corr.		+ .008

ζ Ophiuchi.

R. A., 16^h 31^m $15^s.958$.

Dec., −10° 21′.

Circle West.

1893	July 26	0.00
Corr.		+ .004

Circle East.

1893	July 18	−0.04
	19	− .02
	21	− .02
	23	+ .04
Mean		−0.010
Corr.		− .004

η Herculis.

R. A., 16^h 39^m $13^s.641$.

Dec., 39° 7′.

Circle West.

1893	July 26	+0.01
Corr.		− .017

Circle East.

1893	July 18	−0.03
	21	− .01
Mean		−0.020
Corr.		+ .017

B. A. C. 5647.

R. A., 16^h $44^m.6$.

Dec., 13° 26′.

Circle West.

1893	July 26	38.26
	28	38.26
	29	38.27
Mean		38.263

Circle East.

1893	July 18	38.22
	19	38.23
	21	38.23
Mean		38.227

κ Ophiuchi.

R. A., 16^h 52^m $36^s.199$.

Dec., 9° 32′.

Circle West.

1893	June 19	−0.02
	26	− .02
	27	− .02
	28	− .02
	July 1	+ .02
	3	+ .02
	8	+ .04
	26	+ .05
Mean		+0.006

Circle East.

1893	June 16	+0.03
	July 10	− .02
	11	− .01
	15	− .04
	17	− .07
	18	− .03
	19	− .02
	21	− .01
	23	− .02
Mean		−0.021

η Ophiuchi.

R. A., 17^h 4^m $14^s.436$.

Dec., −15° 35′.

Circle West.

1893	June 19	+0.04
	26	+ .02
	27	+ .04
	28	− .02
	July 1	− .02
	3	.00
	8	− .01
	26	+ .02
Mean		+0.009

Circle East.

1893	June 16	+0.05
	July 10	+ .03
	11	+ .05
	15	+ .03
	17	+ .04
	18	− .01
	19	+ .04
	21	+ .02

1893	July	22	+ .05
Mean			+0.033

U Ophiuchi.

R. A., 17^h^ 11^m^.1.

Dec., 1° 20′.

Circle West.

1893	June	19	5.97
		26	6.01
		27	5.91
		28	5.97
	July	1	6.00
		3	5.96
		8	5.97
Mean			5.970

Circle East.

1893	June	16	5.97
	July	10	5.93
		11	5.92
		15	5.88
		17	5.89
		18	5.83
		19	5.95
		21	5.90
		22	5.91
Mean			5.909

B. A. C. 5903.

R. A., 17^h^ 23^m^.4.

Dec., 0° 25′.

Circle West.

1893	June	19	22.17
		26	22.14
		27	22.14
1893	June	28	22.12
	July	1	22.14
		3	22.16
		8	22.13
Mean			22.143

Circle East.

1893	June	16	22.10
	July	10	22.17
		11	22.15
		15	22.11
		17	22.10
		18	22.14
		19	22.13
		21	22.12
		22	22.07
Mean			22.121

α Ophiuchi.

R. A., 17^h^ 29^m^ 58^s^.055.

Dec., 12° 38′.

Circle West.

1893	June	19	−0.01
		26	+ .02
		27	− .07
		28	− .04
	July	1	.00
		3	− .03
		8	.00
Mean			−0.019

Circle East.

1893	June	16	−0.09
	July	10	− .04
		11	− .05
		15	− .04
1893	July	17	− .02
		18	− .02
		19	− .01
		21	− .01
		22	− .05
Mean			−0.037

ξ Serpentis.

R. A., 17^h^ 31^m^ 27^s^.586.

Dec., −15° 19′.

Circle West.

1893	June	19	−0.02
		26	+ .01
		27	− .01
		28	+ .01
	July	1	− .04
		3	− .01
		8	− .03
Mean			−0.013

Circle East.

1893	June	16	+0.04
	July	10	+ .04
		11	+ .05
		15	+ .02
		17	.00
		18	+ .01
		19	+ .01
		21	+ .04
		22	+ .02
Mean			+0.026

Ll. 32200.

R. A., 17^h^ 34^m^.4.

Dec., −0° 34′.

Circle West.

1893	June	19	27.34
		26	27.35
		27	27.37
		28	27.34
	July	1	27.33
		3	27.34
		8	27.36
Mean			27.347

Circle East.

1893	June	16	27.30
	July	10	27.35
		11	27.32
		15	27.28
		17	27.28
		18	27.31
		19	27.32
		21	27.31
		22	27.31
Mean			27.309

β Ophiuchi.

R. A., 17^h 38^m $11^s.177$.

Dec., 4° 37′.

Circle West.

1893	June	19	−0.01
		26	+ .04
		27	+ .01
		28	− .01
	July	1	+ .03
		3	+ .02
		8	− .02
Mean			+0.009

Circle East.

1893	June	16	+0.02
	July	10	+ .02
		11	− .01
		15	.00
		17	+ .03
		18	+ .05
		19	.00
		21	+ .01
		22	.00
Mean			+0.013

γ Ophiuchi.

R. A., 17^h 42^m $31^s.616$.[1]

Dec., 2° 44′.

Circle West.

1893	June	19	−0.02
		26	+ .03
		27	+ .02
		28	.00
	July	1	+ .02
		3	− .01
		8	− .01
Mean			+0.004

Circle East.

1893	June	16	−0.01
	July	10	+ .01
		11	+ .02
		15	− .02
		17	+ .01
		18	+ .02
		19	+ .02
		21	+ .01
		22	+ .02
Mean			+0.009

1. Corr. to *B. J.* from *Pub. W. O.* VIII not adopted.

ν Ophiuchi.

R. A., 17^h 53^m $8^s.127$.

Dec., −9° 45′.

Circle West.

1893	June	19	+0.01
		26	− .02
		27	− .04
		28	− .06
	July	1	− .06
		3	+ .02
		8	− .01
Mean			−0.023

Circle East.

1893	June	16	0.00
	July	10	− .03
		11	− .01
		15	− .02
		17	+ .01
		18	.00
		19	+ .01
		21	.00
		22	.00
Mean			−0.004

67 Ophiuchi.

R. A., 17^h 55^m $17^s.151$.

Dec., 2° 56′.

Circle West.

1893	June	19	−0.02
		26	− .04
		27	− .02

1893	June 28	.00
	July 1	− .11
	3	.00
	8	+ .02
Mean		−0.024

Circle East.

1893	June 16	−0.05
	July 10	− .03
	11	− .01
	15	− .05
	17	+ .01
	18	− .08
	19	.00
	21	− .01
	22	− .02
Mean		−0.027

η Serpentis.

R. A., 18h 15m 46s.358.

Dec., −2° 55′.

Circle West.

1893	June 19	+0.02
	26	− .01
	27	+ .08
	28	+ .09
	July 1	− .06
	3	+ .04
	8	+ .02
Mean		+0.026

Circle East.

1893	June 16	+0.03
	July 10	+ .06
	11	+ .01
	17	+ .05
	18	+ .02
	19	+ .06
	21	− .02
	22	+ .04
Mean		+0.031

5 H. Scuti.

R. A., 18h 37m 41s.593.

Dec., −8° 22′.

Circle West.

1893	June 19	−0.02
	26	− .04
	27	.00
	28	+ .06
	July 1	+ .07[1]
	3	+ .01
	8	+ .03
Mean		+0.016

Circle East.

1893	June 16	−0.04
	July 10	− .03
	11	− .02
	15	+ .09[2]
	17	− .05
	18	− .08
	19	− .05
	21	− .03
	22	− .04
Mean		−0.028

1. Very faint. Clouds.
2. Poor seeing. Clouds.

110 Herculis.

R. A., 18h 41m 8s.383.

Dec., 20° 26′.

Circle West.

1893	June 19	+0.05
	26	.00
	27	− .01
	28	+ .02
	July 1	.00
	3	− .03
	8	+ .02
Mean		+0.007

Circle East.

1893	June 16	+0.02
	July 10	− .04
	11	.00
	15	.00
	17	+ .01
	18	+ .03
	19	.00
	21	+ .02
	22	+ .03
Mean		+0.008

θ Serpentis *pr.*

R. A., 18h 50m 58s.995.

Dec., 4° 3′.

Circle West.

1893	June 19	+0.01
	26	− .01
	27	− .01
	28	.00
	July 1	+ .06

1898	July	3	− .03
		8	.00
Mean			+0.006

Circle East.

1898	June	16	0.00
	July	10	.00
		11	.00
		15	− .02
		17	+ .02
		18	+ .04
		19	+ .03
		21	+ .02
		22	− .01
Mean			+0.009

g Aquilae.

R. A., $18^h\ 57^m.3$.

Dec., −8° 51′.

Circle West.

1898	June	19	16.36
		26	16.34
		27	16.35
		28	16.38
	July	3	16.40
		8	16.35
Mean			16.368

Circle East.

1898	June	16	16.35
	July	10	16.37
		11	16.39
		15	16.46[1]
		17	16.35
		18	16.34

1. Broken transit, through clouds.

1898	July	19	16.34
		21	16.33
		22	16.35
Mean			16.364

λ Aquilae.

R. A., $19^h\ 0^m\ 34^s.235$.

Dec., −5° 2′.

Circle West.

1898	June	19	+0.01
		26	− .03
		27	− .03
		28	− .04
	July	3	− .03
		8	− .03
Mean			−0.025

Circle East.

1898	June	16	+0.01
	July	10	− .07
		11	− .01
		15	+ .03
		17	.00
		18	− .04
		19	+ .02
		21	+ .01
		22	− .03
Mean			−0.003

δ Aquilae.

R. A., $19^h\ 20^m\ 6^s.189$.

Dec., 2° 54′.

Circle West.

1898	June	19	+0.04
		26	.00
		27	.00
		28	.00
	July	3	+ .01
		8	+ .01
Mean			+0.010

Circle East.

1898	June	16	+0.06
	July	11	+ .04
		17	+ .04
		18	− .02
		19	+ .03
		21	+ .04
		22	− .02
Mean			+0.024

ν Aquilae.

R. A., $19^h\ 21^m.0$.

Dec., 0° 7′.

Circle West.

1898	June	19	2.74
		26	2.69
		27	2.78
		28	2.74
	July	3	2.69
		8	2.68
Mean			2.712

Circle East.

1898	June	16	2.71
	July	10	2.71
		11	2.69
		17	2.73
		18	2.71
		19	2.70

1893	July	21	2.70
		22	2.71
Mean			2.708

ι Aquilae.

R. A., 19^h $31^m.2$.

Dec., $-1°$ 31′.

Circle West.

1893	June	19	11.14
		26	11.14
		27	11.17
		28	11.19
	July	3	11.14
		8	11.11
Mean			11.148

Circle East.

1893	June	16	11.13
	July	10	11.14
		11	11.14
		17	11.11
		18	11.20
		19	11.16
		21	11.14
		22	11.15
Mean			11.146

γ Aquilae.

R. A., 19^h 41^m $10^s.341$.

Dec., 10° 21′.

Circle West.

1893	June	19	0.00
		26	+ .04
		27	+ .06
		28	+ .06
	July	3	− .02
		8	+ .02
Mean			+0.027

Circle East.

1893	July	10	+0.04
		11	− .01
		17	.00
		18	+ .08
		19	− .01
		21	+ .03
		22	+ .01
Mean			+0.020

η Aquilae.

R. A., 19^h 47^m $1^s.323$.[1]

Dec., 0° 43′.

Circle West.

1893	June	19	−0.03
		26	.00
		27	− .02
		28	− .01
	July	3	+ .06
		8	− .02
Mean			−0.003

Circle East.

1893	June	16	−0.03
	July	10	+ .03
		11	+ .01
		17	− .04
		18	+ .01
		19	− .05
		21	− .04
		22	+ .01
Mean			−0.012

1. Corr. to *B. J.* from *Pub. W. O.* VIII not adopted.

β Aquilae.

R. A., 19^h 50^m $3^s.450$.

Dec., 6° 8′.

Circle West.

1893	June	19	−0.01
		26	.00
		27	+ .03
		28	− .03
	July	3	− .01
		8	− .04
Mean			−0.010

Circle East.

1893	June	16	−0.04
	July	11	− .02
		17	− .04
		18	+ .09
		19	− .03
		21	+ .01
		22	− .01
Mean			−0.004

γ Aquarii.

R. A., 22^h 16^m $7^s.778$.

Dec., $-1°$ 55′.

Circle West.

1892	Oct.	15	−0.02
		18	− .10
		19	− .06
		21	+ .01
		22	− .02
		27	+ .02
Mean			−0.028

Circle East.

1892	Sep. 29	−0.02
	Oct. 2	− .03
	4	− .07
	5	+ .03
	8	+ .03
Mean		−0.012

3 Lacertae.[1]

R. A., 22^h 19^m $21^s.098$.

Dec., 51° 41′.

Circle West.

1892	Oct. 15	+0.05
	18	+ .08
	19	+ .15
	21	+ .08
	22	+ .04
	27	+ .09
Mean		+0.082

Circle East.

1892	Sep. 28	+0.09
	29	+ .04
	Oct. 2	.00
	5	− .14[2]
	8	− .09
Mean		−0.020

1. Not used as a clock star.
2. Seeing very poor.

ζ Aquarii *med.*

R. A., 22^h $23^m.3$.

Dec., −0° 35′.

Circle West.

1892	Oct. 15	19.31
	18	19.28
1892	Oct. 19	19.26
	21	19.33
	22	19.30
	27	19.34
Mean		19.303

Circle East.

1892	Sep. 28	19.34
	29	19.26
	Oct. 2	19.31
	5	19.32
	8	19.30
Mean		19.306

η Aquarii.

R. A., 22^h 29^m $51^s.465$.

Dec., −0° 40′.

Circle West.

1892	Oct. 15	+0.04
	18	+ .06
	19	− .02
	21	+ .05
	22	+ .01
	27	+ .01
Mean		+0.025

Circle East.

1892	Sep. 23	+0.02
	28	+ .06
	29	+ .02
	Oct. 2	+ .02
	5	+ .08
	8	+ .03
Mean		+0.038

ζ Pegasi.

R. A., 22^h 36^m $7^s.503$.

Dec., 10° 16′.

Circle West.

1892	Oct. 15	+0.02
	18	− .04
	19	+ .06
	21	− .07
	22	+ .06
	27	− .01
Mean		+0.003

Circle East.

1892	Sep. 23	+0.04
	29	− .01
	Oct. 2	+ .01
	5	− .02
	8	− .02
Mean		0.000

λ Pegasi.

R. A., 22^h 41^m $29^s.616$.

Dec., 23° 0′.

Circle West.

1892	Oct. 15	−0.01
	18	+ .01
	19	+ .03
	21	.00
	22	− .02
	27	− .01
Mean		0.000

Circle East.

1892	Sep. 28	−0.04
	29	− .03
	Oct. 2	− .04

1892	Oct.	5	− .15
		8	− .05
Mean			−0.062

λ Aquarii.

R. A., 22h 47m 1s.930.

Dec., −8° 8′.

Circle West.

1892	Oct.	15	−0.03
		18	+ .01
		19	− .01
		21	+ .03
		22	− .02
		27	.00
Mean			−0.003

Circle East.

1892	Sep.	23	+0.02
		28	− .02
		29	+ .03
	Oct.	2	+ .05
		4	+ .03
		5	+ .02
		8	+ .02
Mean			+0.021

β Piscium.

R. A., 22h 58m.4

Dec., 3° 13′.

Circle West.

1892	Oct.	15	25.85
		18	25.91
		19	25.88
		21	25.92
		22	25.88
1892	Oct.	27	25.87
Mean			25.885

Circle East.

1892	Sep.	23	25.86
		28	25.89
		29	25.90
	Oct.	2	25.88
		5	25.91
		8	25.91
Mean			25.892

π Cephei.[1]

R. A., 23h 4m 29s.662.

Dec. 74° 48′.

Circle West.

1892	Oct.	15	+0.28
		19	+ .38
		21	+ .33
		27	+ .23
Mean			+0.305

Circle East.

1892	Sep.	23	+0.23
	Oct.	4	+ .05
		5	+ .03
		8	+ .01
Mean			+0.080

1. Not used for determining the constant *n*.

φ Aquarii.

R. A., 23h 8m 46s.885.[1]

Dec. −6° 38′.

Circle West.

1892	Oct.	15	−0.05
		18	− .04
		19	− .05
		21	− .08
		22	− .08
		27	− .06
Mean			−0.052

Circle East.

1892	Sep.	23	−0.01
		28	− .02
		29	− .05
	Oct.	2	− .08
		5	+ .02
		8	− .02
Mean			−0.027

1. Authority, American Ephemeris, 1893.

γ Piscium.

R. A., 23h 11m 37s.080.

Dec. 2° 41′.

Circle West.

1892	Oct.	15	0.00
		18	− .01
		19	+ .06
		21	+ .05
		22	+ .04
		27	− .05
Mean			+0.015

Circle East.

1892	Sep.	23	+0.03
		28	− .01
		29	+ .02
	Oct.	2	.00
		4	+ .01
		5	+ .01
		8	.00
Mean			+0.009

τ Pegasi.

R. A., 23^h 15^m $20^s.425$.

Dec., 23° 9′.

Circle West.

1892 Oct.	21	+0.03
	22	.00
	27	− .04
Mean		−0.003
Corr.		− .009

Circle East.

1892 Sep.	23	−0.05
Corr.		+ .009

κ Piscium.

R. A., 23^h 21^m $26^s.834$.

Dec., 0° 40′.

Circle West.

1892 Oct.	15	+0.03
	18	+ .02
	19	+ .02
	21	− .01
	22	+ .10
	27	− .05
Mean		+0.018

Circle East.

1892 Sep.	23	−0.04
	29	+ .02
Oct.	2	− .01
	4	.00
	5	.00
	8	− .01
Mean		−0.007

70 Pegasi.

R. A., 23^h 23^m $44^s.564$.

Dec., 12° 10′.

Circle West.

1892 Oct.	15	+0.03
	18	.00
	19	+ .01
	21	+ .01
	22	− .02
	27	− .02
Mean		+0.002

Circle East.

1892 Sep.	23	−0.02
	28	− .04
	29	− .04
Oct.	2	+ .04
	4	+ .03
	5	− .02
	8	− .03
Mean		−0.011

λ Andromedae.

R. A., 23^h 32^m $19^s.605$.

Dec., 45° 52′.

Circle West.

1892 Oct.	15	+0.02
	18	+ .05
	19	+ .02
	21	+ .02
	22	.00
	27	.00
Mean		+0.018
Corr.		− .044

Circle East.

1892 Oct.	4	−0.02
	5	− .17
	8	− .08
Mean		−0.090
Corr.		+ .044

ι Piscium.

R. A., 23^h 34^m $26^s.776$.

Dec., 5° 2′.

Circle West.

1892 Oct.	15	−0.02
	18	.00
	19	− .03
	21	− .05
	22	− .03
	27	− .02
Mean		−0.025

Circle East.

1892 Sep.	29	+0.01
Oct.	2	.00
	5	.00
	8	− .02
Mean		−0.002

A² Aquarii.

R. A., 23^h $36^m.2$.

Dec., −18° 25′.

Circle West.

1892 Oct.	15	12.52
	18	12.50
	19	12.48
	21	12.49

1892 Oct. 22		12.43
	27	12.44
Mean		12.477

Circle East.

1892 Sep. 23		12.51
	28	12.51
	29	12.54
	Oct. 2	12.53
	5	12.51
	8	12.49
Mean		12.515

Lac. δ Sculptoris.

R. A., 23^h 43^m $21^s.068$.

Dec., $-28°$ $43'$.

Circle West.

1892 Oct. 21		+0.02
	22	+ .01
	27	+ .06
Mean		+0.030

φ Pegasi.

R. A., 23^h 47^m $2^s.614$.

Dec., $18°$ $31'$.

Circle West.

1892 Oct. 15		+0.03
	18	+ .07
	19	+ .04
	21	− .01
	22	− .01
	27	+ .04
Mean		+0 027

Circle East.

1892 Sep. 23		0.00
	28	+ .04
	29	.00
	Oct. 2	− .04
	5	− .02
	8	+ .02
Mean		0.000

ω Piscium.

R. A., 23^h 53^m $48^s.978$.

Dec., $6°$ $16'$.

Circle West.

1892 Oct. 15		0.00
	18	− .04
	19	− .05
	21	− .01
	22	− .06
	27	− .02
Mean		−0.030

Circle East.

1892 Sep. 23		−0.02
	28	− .02
	29	+ .01
	Oct. 2	.00
	5	.00
	8	+ .03
Mean		0.000

Catalogue of Right Ascensions,

1893.0.

TABLE III. CATALOGUE OF RIGHT ASCENSIONS FOR 1893.0.

Name of Star.	*Mag.*	*R. A.* 1893.0.			*Epoch.* 1890+	*No. Obs.*	*Decl.*	
		h	m	s			°	′
β Cassiopeiae	2.0	0	3	28.098	2.78	11	58	34
ι Ceti	3.3	0	13	58.549	2.78	11	− 9	25
ε Piscium	4.0	0	57	23.336	2.95	10	7	19
f Piscium	5.0	1	12	16.725	2.98	12	3	3
ϑ Ceti	3.0	1	18	40.472	2.97	13	− 8	44
μ Piscium	5.1	1	24	34.680	2.96	12	5	34
η Piscium	3.6	1	25	45.398	2.96	12	14	43
B. D.−0°,258	7.2	1	34	33.569	2.97	11	− 0	48
o Piscium	4.1	1	39	44.553	2.96	12	8	37
ζ Ceti	3.0	1	46	10.730	2.96	11	−10	52
ξ Piscium	4.0	1	48	0.935	2.96	10	2	40
α Piscium, *med.*	4.0	1	56	30.528	2.96	11	2	14
67 Ceti	6.0	2	11	38.760	2.96	12	− 6	55
δ Ceti	4.0	2	33	59.815	2.97	9	− 0	8
γ Ceti	3.3	2	37	45.322	2.96	10	2	47
μ Ceti	4.0	2	39	9.449	2.96	9	9	40
41 Arietis	3.8	2	43	41.072	2.96	11	26	49
η Eridani	3.0	2	51	11.963	2.97	11	− 9	19
α Ceti	2.7	2	56	41.131	2.96	12	3	40
δ Arietis	4.1	3	5	30.561	2.96	12	19	19
o Tauri	3.6	3	19	3.265	2.96	11	8	39
f Tauri	4.0	3	24	57.872	2.96	12	12	34
ε Eridani	3.0	3	27	53.321	2.96	10	− 9	49
10 Tauri	4.5	3	31	24.675	2.96	10	0	4
η Tauri	3.0	3	41	7.382	2.96	11	23	46

Name of Star.	Mag.	R. A. 1893.0.	Epoch. 1890+	No. Obs.	Decl.
		h m s			° ′
32 Eridani	5.0	3 48 55.037	2.96	10	− 3 16
λ Tauri	4..	3 54 45.065	3.03	19	12 11
ν Tauri	4.0	3 57 27.808	3.03	22	5 42
μ Tauri	4.5	4 9 43.389	3.05	12	8 37
δ Tauri	4.0	4 16 45.795	3.11	5	17 17
ε Tauri	3.6	4 22 22.076	3.04	12	18 56
ν Eridani	3.3	4 30 58.325	3.04	12	− 3 34
π^5 Orionis	4.0	4 48 40.623	3.10	15	2 15
β Eridani	3.0	5 2 35.314	3.11	15	− 5 13
o Orionis	4.7	5 16 17.983	3.11	13	− 0 29
γ Orionis	2.0	5 19 23.499	3.11	13	6 15
119 Tauri	4.7	5 25 56.369	3.11	12	18 30
ι Orionis	3.1	5 30 11.903	3.11	12	− 5 58
κ Orionis	2.6	5 42 40.866	3.11	12	− 9 42
ϑ Aurigae	3.0	5 52 25.523	3.10	9	37 12
μ Geminorum	3.0	6 16 29.239	3.11	8	22 34
10 Monocerotis	5.0	6 22 40.530	3.11	3	− 4 41
γ Geminorum	2.3	6 31 31.837	3.11	12	16 29
ε Geminorum	3.3	6 37 20.970	3.11	12	25 14
ξ Geminorum	3.6	6 39 17.037	3.11	12	13 0
ϑ Canis Majoris	4.3	6 49 13.084	3.11	12	−11 54
19 Monocerotis	4.8	6 57 36.012	3.11	12	− 4 5
λ Geminorum	3.8	7 11 56.639	3.11	12	16 43
δ Geminorum	3.3	7 13 43.990	3.11	12	22 10
β Canis Minoris	3.0	7 21 20.864	3.10	9	8 30
α Cancri	4.0	8 52 38.130	3.24	9	12 16
ϑ Hydrae	4.0	9 8 47.853	3.24	10	2 45
23 Hydrae	5.5	9 11 22.910	3.23	10	− 5 54
α Hydrae	2.0	9 22 19.792	3.25	8	− 8 11
ι Hydrae	4.1	9 34 23.491	3.25	10	− 0 39

Name of Star.	Mag.	R. A. 1893.0.			Epoch. 1890+	No. Obs.	Decl.	
		h	m	s			°	′
ο Leonis	3.6	9	35	26.394	3.25	10	10	22
ε Leonis	3.0	9	39	46.661	3.25	10	24	16
6 Sextantis	6.1	9	45	50.541	3.25	10	− 3	44
η Leonis	3.3	10	1	29.945	3.25	9	17	17
α Leonis	1.3	10	2	40.433	3.25	10	12	29
λ Hydrae	4.0	10	5	22.306	3.26	9	−11	49
ζ Leonis	3.0	10	10	44.339	3.26	9	23	57
μ Hydrae	4.0	10	20	54.932	3.28	13	−16	17
33 Sextantis	6.4	10	35	57.588	3.27	13	− 1	10
l Leonis	5.1	10	43	37.968	3.27	13	11	6
p^2 Leonis	5.0	10	56	22.177	3.26	11	− 1	53
ϑ Leonis	3.3	11	8	37.500	3.26	11	16	0
δ Crateris	3.8	11	13	59.440	3.28	12	−14	11
σ Leonis	4.1	11	15	37.123	3.28	11	6	36
υ Leonis	4.8	11	31	28.188	3.28	11	− 0	13
β Virginis	3.8	11	45	7.287	3.28	12	2	22
95 Leonis	5.6	11	50	10.321	3.28	11	16	14
ο Virginis	4.0	11	59	45.495	3.28	11	9	19
ε Corvi	3.0	12	4	37.272	3.31	20	−22	1
γ Corvi	2.0	12	10	18.162	3.30	21	−16	56
c Virginis	5.2	12	14	54.894	3.38	12	3	55
δ Corvi	2.3	12	24	19.640	3.38	13	−15	55
δ Virginis	3.0	12	50	12.786	3.38	12	3	58
ε Virginis	2.6	12	56	51.004	3.38	13	11	32
ϑ Virginis	4.3	13	4	24.540	3.38	12	− 4	58
B. D. + 2°,2664	5.6	13	16	15.172	3.38	13	2	38
α Virginis	1..	13	19	33.321	3.38	13	−10	36
ζ Virginis	3.3	13	29	14.418	3.38	12	− 0	2
τ Bootis	4.6	13	42	10.631	3.38	11	17	59
89 Virginis	5.0	13	44	3.417	3.38	11	−17	36

Name of Star.	*Mag.*	*R. A.* 1893.0. *h*	*m*	*s*	*Epoch.* 1890+	*No. Obs.*	*Decl.* °	′
η Bootis	3.0	13	49	35.378	3.38	10	18	56
τ Virginis	4.0	13	56	12.012	3.38	11	2	3
ι Virginis	4.0	14	10	24.160	3.38	11	− 5	29
φ Virginis	5.0	14	22	41.306	3.38	11	− 1	44
ρ Bootis	3.6	14	27	13.095	3.38	10	30	50
π Bootis, *pr.*	4.3	14	35	41.835	3.38	12	16	52
μ Virginis	4.0	14	37	25.228	3.39	14	− 5	11
ε Bootis (a)	2.6	14	40	18.811	3.40	13	27	31
109 Virginis	3.6	14	40	50.318	3.39	13	2	20
110 Virginis	4.6	14	57	29.606	3.39	14	2	30
ι Librae	4.6	15	6	7.259	3.40	13	−19	23
3 Serpentis	5.8	15	9	52.170	3.40	11	5	20
β Librae	2.0	15	11	14.904	3.40	13	− 8	59
β Coronae Borealis	3.8	15	23	25.009	3.41	13	29	28
37 Librae	5.0	15	28	19.751	3.41	13	− 9	41
β Serpentis	3.3	15	41	14.928	3.41	13	15	45
ε Coronae Borealis	4.0	15	53	9.441	3.41	13	27	11
ι Coronae Borealis	4.2	15	57	9.371	3.41	13	30	8
δ Ophiuchi	3.0	16	8	44.276	3.41	13	− 3	25
ε Ophiuchi	3.3	16	12	39.564	3.42	9	− 4	25
γ Herculis	3.1	16	17	11.958	3.42	10	19	24
β Herculis	2.8	16	25	37.155	3.56	4	21	43
ζ Ophiuchi	2.6	16	31	15.948	3.56	5	−10	21
η Herculis	3.1	16	39	13.637	3.56	3	39	7
B. A. C. 5647	5.6	16	44	38.245	3.56	6	13	26
κ Ophiuchi	3.3	16	52	36.191	3.52	17	9	32
η Ophiuchi	2.3	17	4	14.457	3.52	17	−15	35
U Ophiuchi	5.9	17	11	5.939	3.51	16	1	20
B. A. C. 5903	5.3	17	23	22.132	3.51	16	0	25
α Ophiuchi	2.0	17	29	58.027	3.51	16	12	38

Name of Star.	*Mag.*	*R. A.* 1893.0.			*Epoch.* 1890+	*No. Obs.*	*Decl.*	
		h	m	s			°	′
ξ Serpentis	3.6	17	31	27.543	3.51	16	−15	19
Ll. 32200	6.5	17	34	27.328	3.51	16	− 0	34
β Ophiuchi	3.0	17	38	11.188	3.51	16	4	37
γ Ophiuchi	3.6	17	42	31.623	3.51	16	2	44
ν Ophiuchi	3.6	17	53	8.114	3.51	16	− 9	45
67 Ophiuchi	4.0	17	55	17.125	3.51	16	2	56
η Serpentis	3.0	18	15	46.387	3.51	15	− 2	55
5 H. Scuti	5.0	18	37	41.587	3.51	16	− 8	22
110 Herculis	4.0	18	41	3.391	3.51	16	20	26
ϑ Serpentis, *pr.*	4.2	18	50	54.003	3.51	16	4	3
g Aquilae	5.5	18	57	16.364	3.51	15	− 3	51
λ Aquilae	3.1	19	0	34.221	3.51	15	− 5	2
δ Aquilae	3.3	19	20	6.206	3.51	13	2	54
ν Aquilae	4.8	19	21	2.710	3.51	14	0	7
ι Aquilae	4.4	19	31	11.147	3.51	14	− 1	31
γ Aquilae	3.0	19	41	10.364	3.52	13	10	21
η Aquilae	4..	19	47	1.315	3.51	14	0	43
β Aquilae	4.0	19	50	3.443	3.51	13	6	8
γ Aquarii	3.4	22	16	7.753	2.78	11	− 1	55
3 Lacertae	4.4	22	19	21.129	2.78	11	51	41
ζ Aquarii, *med.*	3.8	22	23	19.304	2.77	11	− 0	35
η Aquarii	3.8	22	29	51.497	2.78	12	− 0	40
ζ Pegasi	3.3	22	36	7.505	2.78	11	10	16
λ Pegasi	4.0	22	41	22.585	2.78	11	23	0
λ Aquarii	4.0	22	47	1.939	2.77	13	− 8	8
β Piscium	4.6	22	58	25.889	2.78	12	3	13
π Cephei	4.6	23	4	29.854	2.78	8	74	48
φ Aquarii	4.3	23	8	46.845	2.78	12	− 6	38
γ Piscium	4.0	23	11	37.092	2.77	13	2	41
τ Pegasi	4.6	23	15	20.406	2.79	4	23	9

Name of Star.	*Mag.*	*R. A.* 1893.0.	*Epoch.* 1890+	*No. Obs.*	*Decl.*
		h *m* *s*			° ′
κ Piscium	5.8	23 21 26.830	2.78	12	0 40
70 Pegasi	5.0	23 23 44.559	2.78	13	12 10
λ Andromedae	4.0	23 32 19.572	2.79	9	45 52
ι Piscium	4.3	23 34 26.762	2.78	10	5 2
A² Aquarii	4.6	23 36 12 496	2.78	12	−18 25
Lac δ Sculptoris	4.4	23 43 21.098	2.81	3	−28 43
φ Pegasi	5.6	23 47 2.628	2.78	12	18 31
ω Piscium	4.0	23 53 48.963	2.78	12	6 16

The End of Vol. IX.

ERRATA—VOL. IX.

The following errata have been detected while the present volume was in press:

Page 16, line 5. At end of line for $a' \, p'$ read $a_1 \, p_1$.

Page 19, line 31. Insert ξ after the word affect.

Page 21, line 16. For z^1_1, z^1_2 read z'_1, z'_2.

Page 24, line .... Introduce after the table the following foot notes: [1]Unsatisfactory observation. [2]Adjusted i_0 after this determination. [3]Telescope was probably disturbed in the reversal. [4]Reel and objective removed from telescope and cleaned just prior to this determination.

Page 53. Insert Δ at top of column 7.

Page 53, last line. For 0 Pegasi, read 70 Pegasi.

Page 60, first line. For last word read Standard.

Page 62, line four from bottom. For pa read pair.

Page 63, pagination. For 53 read 63.

Page 63, line 12. For left read right.

Page 170, line 6. For $+0.140\,a$ read $-0.140\,a$.

Page 208, lines 15 and 16. For "changed" read "opposite to that for a star south of the zenith."

Page 208, lines 8 and 12 from bottom. For $T_i - T_o$ read $\pm (T_i - T_o)$.

Page 208, line 11 from bottom: After cos δ insert, "without regard to the sign of the latter."

Page 208, line 7 from bottom. For *di* read *di* sec δ.

Page 214, line 12 from bottom. Insert 3 before 8.

Page 222, μ Piscium. Following 1893, January 13 insert January 14.
η Piscium, *Circle West*, Mean. For —0.027 read +0.027.
B. D. —0°.258. Following 1892, November insert December.

Page 223, δ Ceti, 1892, Dec. 10, read —.05. Dec. 17, read —.04. Mean, read —0.024. 1893, Jan. 10, read [+.28][1].

Page 226, λ Tauri, 1893, Jan. 14, read +.03.

Page 227, π^5 Orionis, 1893, Mar. 1, read +.04. Mean, for +0.007 read −0.007.

Page 230, 19 Monocerotis, R. A. For 5^h read 6^h.

Page 232, 6 Sextantis. *Circle East*, first obs. read Mar. 4.

Page 236, θ Virginis. 1893, May 20, read —.04.

Page 237, η Bootis. *Circle East*, first obs. read 1893, May 18.